JC05 Rec'd PCT/PTO 20 FEB 2002

FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEY'S DOCKET NUMBER **GRP-0012** U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR **10/069559**
INTERNATIONAL APPLICATION NO. **PCT/DK00/00464**	INTERNATIONAL FILING DATE **21 August 2000**	PRIORITY DATE CLAIMED **20 August 1999**

TITLE OF INVENTION
EMG CONTROL OF PROSTHESIS

APPLICANT(S) FOR DO/EO/US
RONALD R. RISO

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☐ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☐ Other items or information:

"Express Mail" mailing label number EL871056557US
Date of Deposit February 20, 2002
I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231.

Jennifer Watson
(Typed or printed name of person mailing paper or fee)

(Signature of person mailing paper or fee)

PCTUS1/REV03

20 FEB 2002

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
10/069559	PCT/DK00/00464	GRP-0012

24. The following fees are submitted:.

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :		
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1040.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$740.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$890.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	22 - 20 =	2	x $18.00	**$36.00**	
Independent claims	2 - 3 =	0	x $84.00	**$0.00**	
Multiple Dependent Claims (**check if applicable**).			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$926.00**	
☒ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				**$463.00**	
SUBTOTAL =				**$463.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$463.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (**check if applicable**). ☐				**$0.00**	
TOTAL FEES ENCLOSED =				**$463.00**	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of **$463.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ______ in the amount of ______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 06-1130 A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Daniel F. Drexler
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55 Griffin Road South
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Customer No. 23413
Telephone: 860-286-2929

SIGNATURE

Daniel F. Drexler
NAME

47,535
REGISTRATION NUMBER

February 20, 2002
DATE

10/069559
JC13 Rec'd PCT/PTO 20 FEB 2002

Express Mail Label #EL871056557US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF RONALD R. RISO

FOR: EMG CONTROL OF PROSTHESIS

PRELIMINARY AMENDMENT

The Assistant Commissioner
of Patents and Trademarks
Washington, DC 20231

Sir:

Prior to the Examiner acting in the above-referenced application, please preliminary amend the specification and claims as follows:

IN THE SPECIFICATION:

A substitute specification is submitted along with a marked-up copy thereof as attached hereto.

IN THE CLAIMS

Please replace claims 1-22 with the following rewritten versions:

1. (Amended) A method of controlling a prosthesis, comprising using electromyographic (EMG) signals to generate control signals for one or more prostheses wherein the electromyographic (EMG) signals are received by one or more sets of electrodes dedicated to a source of electromyographic (EMG) signals.

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Jennifer Watson
(Typed or printed name of person mailing paper or fee)

(Signature of person mailing paper or fee)

2. (Amended) Method according to claim 1, wherein said one or more sets of dedicated electrodes is/are placed subcutaneously, epimesially or intramuscularly.

3. (Amended) Method according to claim 1, wherein said one or more sets of dedicated electrodes are implanted in a muscle or muscles.

4. (Amended) Method according to claim 1, wherein the electromyographic (EMG) signals from said one or more sets of dedicated electrodes are transmitted to signal processing means by wireless transmission.

5. (Amended) Method according to claim 4, wherein the electromyographic (EMG) signals from said one or more sets of dedicated electrodes are processed by signal processing means, and wherein control signals for the prostheses are produced, said signal processing means utilizing a pattern recognition method.

6. (Amended) Method according to claim 5, wherein the control signals of the prostheses are generated by utilizing an artificial neural network (ANN).

7. (Amended) Method according to claim 1, wherein the electromyographic (EMG) signals are received by four or more sets of dedicated electrodes placed in relation to at least four muscles or distinct functional muscle compartments.

8. (Amended) Method according to claim 7, wherein said prostheses comprise an artificial arm and/or hand and wherein said one or more sets of electrodes are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus.

9. (Amended) Method according to claim 7, wherein said prostheses comprise an artificial arm and/or hand and wherein said one or more electrodes are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis

Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis.

10. (Amended) Method according to claim 1, wherein two or more sets of dedicated electrodes are placed in relation to at least one muscle, said two or more dedicated electrodes being placed in relation to different parts of said at least one muscle.

11. (Amended) Method according to claim 1, wherein electroneurographic (ENG) signals are received by one or more separate sets of ENG-electrodes and said ENG-signals are used as complimentary signals for generating control signals.

12. (Amended) A system for controlling a prosthesis, wherein electromyographic (EMG) signals are used to generate control signals for one or more artificial limbs the system comprising one or more sets of electrodes, each dedicated to a source of electromyographic (EMG) signals for receipt of the electromyographic (EMG) signals.

13. (Amended) System according to claim 12, wherein said one or more sets of dedicated electrodes is/are configured for subcutaneous, epimesial or intramuscular placing.

14. (Amended) System according to claim 12, wherein said one or more sets of dedicated electrodes is/are configured for an implantation in a muscle or muscles.

15. (Amended) System according to claim 12, further comprising means for transmitting the electromyographic (EMG) signals from said one or more sets of dedicated electrodes to signal processing means by wireless transmission.

16. (Amended) System according to claim 12, further comprising signal processing means for producing control signals for the artificial limb(s), said signal processing means utilizing a pattern recognition method.

17. (Amended) System according to claim12, further comprising an artificial neural network (ANN) for generating control signals for the artificial limb(s).

18. (Amended) System according to claim 12, wherein the system comprises four or more sets of dedicated electrodes placed in relation to at least four muscles or functional distinct muscle compartments for receipt of electromyographic (EMG) signals.

19. (Amended) System according to claim 18, wherein said prostheses comprise an artificial arm and/or hand and wherein one or more sets of electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus.

20. (Amended) System according to claim 18, wherein said prostheses comprise an artificial arm and/or hand and wherein one or more sets of electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis.

21. (Amended) System according to claim 12, wherein the system comprises two or more sets of dedicated electrodes placed in relation to at least one muscle, and said two or more sets of dedicated electrodes is/are placed in relation to different parts of said at least one muscle.

22. (Amended) System according to claim 12, further comprising one or more sets of electroneurographic (ENG) electrodes for receiving electroneurographic (ENG) signals wherein said ENG-signals are used as complimentary signals for generating control signals.

IN THE ABSTRACT:

Please replace the abstract with the following rewritten version:

--A method and a system for controlling a prosthesis such as an artificial limb. Electromyographic (EMG) signals are used to generate control signals for one or more prostheses such as artificial limbs. The electromyographic (EMG) signals are received by one or more sets of electrodes dedicated to a source of electromyographic (EMG) signals. By using dedicated electrodes, electromyographic (EMG) signals originating from well-defined sources may be picked up. Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being would move a part of his body, e.g. a limb or a part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.--

REMARKS

Applicant requests entry of the above-identified amendments which conform the claims to U.S. practice. Further, a substitute specification is submitted along with a marked-up copy thereof pursuant to 37 CFR 1.125(b). No new matter is introduced by this Amendment as antecedent support is set forth in the specification and the original claims.

Prosecution on the merits is respectfully requested.

If there are any charges with respect to this Amendment or otherwise, please charge them to Deposit Account No. 06-1130 maintained by Applicant's attorneys.

Respectfully submitted,
RONALD R. RISO

CANTOR COLBURN LLP
Applicant's Attorney

By: ______________________
Daniel F. Drexler
Registration No. 47,535
Customer No. 23413

Date: 20 February 2002
Tel: 860-286-2929

Version with Markings to Show Changes Made

IN THE CLAIMS:

Claims 1-22 are amended herein as follows.

1. (Amended/Marked Up) A method of controlling a prosthesis [such as an artificial limb, whereby], comprising using electromyographic (EMG) signals [are used]to generate control signals for one or more prostheses [such as artificial limbs and whereby]wherein the electromyographic (EMG) signals are received by one or more sets of electrodes dedicated to a source of electromyographic (EMG) signals.

2. (Amended/Marked Up) Method according to claim 1, [characterized in that] wherein said one or more sets of dedicated electrodes is/are placed subcutaneously, epimesially or intramuscularly.

3. (Amended/Marked Up) Method according to claim 1 [or 2], [characterized in that] wherein said one or more sets of dedicated electrodes are implanted in a muscle or muscles.

4. (Amended/Marked Up) Method according to [one or more of] claim[s] 1[- 3], [characterized in that] wherein the electromyographic (EMG) signals from said one or more sets of dedicated electrodes are transmitted to signal processing means by wireless transmission.

5. (Amended/Marked Up) Method according to [one or more of] claim[s 1 -] 4, [characterized in that] wherein the electromyographic (EMG) signals from said one or more sets of dedicated electrodes are processed by signal processing means, [whereby] and wherein control signals for the [artificial limb(s)]prostheses are produced, said signal processing means utilizing a pattern recognition method.

6. (Amended/Marked Up) Method according to [one or more of] claim[s 1 -] 5, [characterized in that] wherein the control signals of the [artificial limb(s)]prostheses are generated by utilizing an artificial neural network (ANN).

7. (Amended/Marked Up) Method according to [one or more of] claim[s] 1 [- 6], [characterized in that] wherein the electromyographic (EMG) signals are received by four or more sets of dedicated electrodes placed in relation to at least four muscles or distinct functional muscle compartments.

8. (Amended/Marked Up) Method according to claim 7, [characterized in that the method is utilized to control]wherein said prostheses comprise an artificial arm and/or hand and [in that]wherein said one or more sets of electrodes are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus.

9. (Amended/Marked Up) Method according to claim 7, [characterized in that the method is utilized to control]wherein said prostheses comprise an artificial arm and/or hand and [in that]wherein said one or more electrodes are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis.

10. (Amended/Marked Up) Method according to [one or more of] claim[s] 1 [- 9], [characterized in that] wherein two or more sets of dedicated electrodes are placed in relation to at least one muscle, said two or more dedicated electrodes being placed in relation to different parts of said at least one muscle.

11. (Amended/Marked Up) Method according to [one or more of] claim[s] 1 [- 10], [characterized in that] wherein electroneurographic (ENG) signals are received by one or more separate sets of ENG-electrodes and [that these]said ENG-signals are used as complimentary signals for generating control signals.

12. (Amended/Marked Up) A system for controlling a prosthesis, [such as an artificial limb,]wherein electromyographic (EMG) signals are used to generate control signals for one or more artificial limbs[and wherein] the system compris[es]ing one or more sets of electrodes, each dedicated to a source of electromyographic (EMG) signals for receipt of the electromyographic (EMG) signals.

13. (Amended/Marked Up) System according to claim 12, [characterized in that] wherein said one or more sets of dedicated electrodes is/are configured for subcutaneous, epimesial or intramuscular placing.

14. (Amended/Marked Up) System according to claim 12 [or 13], [characterized in that] wherein said one or more sets of dedicated electrodes is/are configured for an implantation in a muscle or muscles.

15. (Amended/Marked Up) System according to [one or more of] claim[s] 12 [- 14], [characterized in that] further comprising [the system comprises] means for transmitting the electromyographic (EMG) signals from said one or more sets of dedicated electrodes to signal processing means by wireless transmission.

16. (Amended/Marked Up) System according to [one or more of] claim[s] 12 [- 15], [characterized in that] further comprising [the system comprises] signal processing means for producing control signals for the artificial limb(s), said signal processing means utilizing a pattern recognition method.

17. (Amended/Marked Up) System according to [one or more of] claim[s] 12 [- 16], [characterized in that] further comprising [the system comprises] an artificial neural network (ANN) for generating control signals for the artificial limb(s).

18. (Amended/Marked Up) System according to [one or more of] claim[s] 12 [- 17], [characterized in that] wherein the system comprises four or more sets of dedicated electrodes placed in relation to at least four muscles or functional distinct muscle compartments for receipt of electromyographic (EMG) signals.

19. (Amended/Marked Up) System according to claim 18, [characterized in that the system is utilized to control]wherein said prostheses comprise an artificial arm and/or hand and wherein one or more sets of electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus.

20. (Amended/Marked Up) System according to claim 18, [characterized in that the system is utilized to control]wherein said prostheses comprise an artificial arm and/or hand and [in that]wherein one or more sets of electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis.

21. (Amended/Marked Up) System according to [one or more of] claim[s] 12 [- 20], [characterized in that] wherein the system comprises two or more sets of dedicated electrodes placed in relation to at least one muscle, and [in that] said two or more sets of dedicated electrodes is/are placed in relation to different parts of said at least one muscle.

22. (Amended/Marked Up) Method according to [one or more of] claim[s] 12 [- 21], [characterized in that the system comprises]further comprising one or more sets of electroneurographic (ENG) electrodes for receiving electroneurographic (ENG) signals [and in that these]wherein said ENG-signals are used as complimentary signals for generating control signals.

IN THE ABSTRACT:

The abstract is rewritten herein as follows:

"A method and a system for controlling a prosthesis such as an artificial limb. Electromyographic (EMG) signals are used to generate control signals for one or more prostheses such as artificial limbs. The electromyographic (EMG) signals are received by one or more sets of electrodes dedicated to a source of electromyographic (EMG) signals. [

]By using dedicated electrodes, electromyographic (EMG) signals originating from well-defined sources may be picked up. Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being would move a part of his body, e.g. a limb or a part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.

[(Fig. 4)]

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EMG CONTROL OF PROSTHESIS

Field of the invention

The invention relates to a method and a system for controlling prostheses such as artificial limbs according to claim 1 and claim 12, respectively.

Background of the invention

The use of prostheses such as artificial limbs, e.g. hands, arms, legs, feet etc. for human beings who have lost a limb, is well-known.

Further, it is known that such artificial limbs may be constructed to provide (limited) movement of the limb in relation to the user or to provide movement between two parts of the limb, for example the turning of an artificial hand in relation to a corresponding artificial arm. These movements, which may be performed with only one or two degrees of freedom, may be body-powered, be powered electrically or controlled by special control arrangements which can be activated by the user, i.e. the wearer of the prosthesis.

Great efforts have been made to develop a user-friendly way of controlling the movement of artificial limbs. Thus, the use of electromyographic signals, also referred to as EMG signals in the following, have been utilized in prior-art to control prostheses or artificial limbs. In prior-art, these signals stemming from muscles which are activated, e.g. contracted or extended, have been picked up by contact electrodes, placed on the skin of a human being in places where residual muscles are present, e.g. in proximity of residual muscles. As one or more of these residual muscles is/are activated by the human being, EMG signals are generated. These electrical signals are picked up by contact electrodes and can be used as input to a control circuit for initiating movement of an artificial limb.

However, the contact electrodes will usually be placed for example on opposing sides of a lower arm or in such a manner that each electrode will pick up EMG signals from more than one muscle, i.e. a group of muscles. However, the signals picked up by these contact electrodes will still be able to provide a sufficient basis for controlling movements with one degree of freedom, for example the opening and closing of a hand in a palmer grasp mode, as the group of muscles on one side of the lower arm will provide a detectable signal of movement in one direction, for example closing of the hand, while the group of muscles on the other side of the lower arm will provide a detectable signal of movement in the other direction, for example opening of the hand. The user of such a prosthesis thus has to learn that once a certain group of muscles is activated, a palmer grip will be performed, and that the palmer grip will be relaxed and the hand will open when a certain other group of muscles is activated.

This has the disadvantage that some sort of training is required before the use of the prosthesis may be mastered by the user. Further, the movements that may be performed by the prosthesis are limited to relatively simple movements, e.g. opening and closing of a hand. However, it will also be possible to configure a prosthesis capable of performing more than one simple movement by having a switch-over function, for example a switch, which may be activated by the user, whereby the prosthesis may perform another movement, for example a pinch grip or a rotation of a wrist. This second movement will also be triggered by EMG signals from the same muscle groups as the first movement, and the activation by the user will thus be complicated and awkward, and the two different movements cannot be performed simultaneously.

The use of more than two sets of contact electrodes, i.e. electrodes applied to the skin of the user, for receiving EMG signals from different muscles or muscle groups will be difficult if not impossible in practice, as two contact electrodes placed for example on the same side of a lower arm will inevitably receive the same EMG signals emitted by the same muscles or muscle groups (cross talk). Consequently, it will be difficult to make a distinction between the signals received from these two contact electrodes and thus make control of two different movements by these signals impossible. Even if it were possible to place two contact electrodes on the same side of an arm in such a manner that the signals picked up by these contact electrodes

arm in such a manner that the signals picked up by these contact electrodes would be distinctly different, i.e. not involving substantial cross talk, it would be necessary to teach the user to activate more than two muscles or muscle groups independently of each other in order to be able to achieve motions of the artificial limb with more than one degree of freedom. Hence, this would involve even more extensive training before the user would be able to master the use of the prosthesis satisfactorily.

Thus, it is an object of the present invention to provide a method and a system for controlling a prosthesis such as an artificial limb, whereby the movement of the prosthesis and/or parts thereof may be performed in a user-friendly manner by the user.

Another object of the invention is to provide a method and a system for controlling a prosthesis such as an artificial limb, whereby the movements of the prosthesis and/or part/parts thereof may be performed in a highly intuitive manner, e.g. a manner, which will be natural to the user.

It is a further object of the invention to provide a method and a system whereby relatively complex movements may be performed by the prosthesis and/or parts thereof.

These and other objects are achieved by the invention.

Summary of the invention

As stated in claim 1, the invention relates to a method of controlling a prosthesis such as an artificial limb, whereby electromyographic (EMG) signals are used to generate control signals for one or more prostheses such as artificial limbs, and whereby the electromyographic (EMG) signals are received by one or more sets of electrodes dedicated to a source of electromyographic (EMG) signals.

By using dedicated electrodes, i.e. electrodes designed and placed in such manner that the signals picked up by each of these sets of electrodes emanate from a predefined source, e.g. a certain muscle or a certain compartment within the muscle, elec-

tromyographic (EMG) signals originating from well-defined sources may be picked up.

Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being should desire to move a part of his body, e.g. a limb or a part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.

Thus, the prosthesis or part of the prosthesis may be moved by the user in a highly intuitive way.

Further, it will be possible to perform relatively complex movements of a prosthesis or part/parts thereof as EMG signals may be received from muscles which would normally have been activated by the user of the prosthesis when performing the natural movements of the missing body part(s). These signals may thus be used to control the corresponding prosthesis parts, whereby the user may perform the desired movements intuitively, i.e. without having to learn to move a particular muscle group(s) in a particular way and/or without having to activate switch-over mechanisms etc.

A further advantage of the invention is related to environmental control, as the EMG control method may be applied for controlling light, appliances etc, which the user desires to control, e.g. turn on and off. Such an environmental control function may be configured in relation to the EMG control method for controlling a prosthesis, whereby the user would be able to control such appliances, for example via wireless control, without actually having to manipulate a control means, e.g. a switch.

The electrodes are constituted by sets of electrodes. In order to pick up an electrical signal, e.g. an electrical potential, a measurement or detection has to be made in at least two (spatially) different places in order to achieve a potential difference. Thus, at least two electrodes constitute a set of electrodes. Evidently, such a set of electrodes may be configured as a unit, whereby the distance between the two measuring

or detection points of the set of electrodes is predefined and kept at a constant by the unit, or the electrodes may be separate parts.

The one or more sets of dedicated electrodes may preferably, as stated in claim 2, be placed subcutaneously, epimesially or intramuscularly, whereby it is ensured that relatively strong EMG signals from the corresponding muscle will be received by the electrode and that these signals will not be influenced by signals stemming from other sources, e.g. other muscles (cross talk).

Further, said one or more sets of dedicated electrodes may be implanted in a muscle or muscles, as stated in claim 3, whereby the EMG signals will be received by the electrodes in a relatively powerful form without any cross talk from other sources of EMG signals.

The muscles, in which the sets of electrodes are implanted, may for example be residual muscles related to a missing part of the body replaced by a prosthesis, e.g. muscles in an arm of a below elbow (BE) amputee. However, the sets of electrodes may be implanted in any residual limb or other muscles as desired in order to improve the EMG signal pattern discriminality. For example, a muscle in a shoulder part of an amputee may provide resourceful EMG signal information relating to the desired movements of for example a hand or an arm.

Preferably, as stated in claim 4, the electromyographic (EMG) signals from said one or more sets of dedicated electrodes may be transmitted to signal processing means by wireless transmission, whereby the disadvantages and/or discomfort associated with signal wires protruding through the skin of the user may be avoided.

In a preferred embodiment, as stated in claim 5, the electromyographic (EMG) signals from said one or more sets of dedicated electrodes are processed by signal processing means, whereby control signals for the artificial limb(s) are produced, said signal processing means utilizing a pattern recognition method. Hereby, the control signals may be produced in an advantageous manner and the control signals may

consistently lead to the desired movements of the prosthesis and/or part/parts thereof irrespective of the fact that the EMG signals may vary in form and/or amplitude.

As stated in claim 6, the control signals of the artificial limb(s) may be generated by utilizing an artificial neural network (ANN), whereby the pattern recognition method may be performed in a particularly advantageous manner.

As stated in claim 7, the electromyographic (EMG) signals may preferably be received by four or more sets of dedicated electrodes, located in relation to at least four muscles, or combinations of distinct functional muscle compartments, whereby a sufficient number of distinct EMG signals may be provided in order to achieve at least four different movements of a limb or part/parts thereof.

As stated in claim 8, the method may be utilized to control an artificial arm and/or hand, whereby one or more sets of electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus. This may provide at least four different movements of the artificial arm or part/parts thereof, for example closing and opening of a hand in a palmer grasp mode and closing and opening of a hand in a lateral grasp (also referred to as a key grip) mode.

As stated in claim 9, the method may be utilized to control an artificial arm and/or hand, whereby one or more sets of electrodes are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis. Hereby, an artificial arm with an even larger degree of freedom may be controlled in a user-friendly and highly intuitive manner by the user. An artificial arm may for example be configured for opening/closing the hand and performing a palmer or a key grip, rotating or flexing the wrist, extending or bending the fingers and the thumb (selectively) etc., making all these functions controllable by the amputee (the user) in a natural and highly intuitive manner.

As stated in claim 10, two or more dedicated sets of electrodes may be placed in relation to at least one muscle, said two or more sets of dedicated electrodes being placed in relation to different parts of said at least one muscle. Hereby, EMG signals from different parts of the muscle may be picked up. These EMG signals may differ and may be used to achieve greater reliability and/or even more complex and detailed patterns of movements performed by a prosthesis such as an artificial limb.

Finally, as stated in claim 11, electroneurographic (ENG) signals may be received by one or more separate sets of ENG-electrodes and these ENG-signals may be used as complimentary signals for generating control signals. Hereby, further information concerning a desired movement may be provided and used to control a prosthesis. In cases where EMG signals may not be recorded, for example EMG signals stemming from muscles, which are absent, in particular the intrinsic muscles of the hand, it may be possible to record corresponding ENG signals, for example from the trunk nerves in the upper arm. These ENG signals will contain information complimentary to the EMG signals, whereby improved control of a prosthesis is provided. The ENG signals from the nerves may be provided in a number of ways known to a person skilled in the art.

The invention also relates to a system for controlling a prosthesis, such as an artificial limb, as claimed in claim 12. According to claim 12, electromyographic (EMG) signals are used to generate control signals for one or more artificial limbs and the system comprises one or more sets of dedicated electrodes, each placed in relation to a muscle, for receipt of the electromyographic (EMG) signals.

By using dedicated electrodes, i.e. electrodes designed and placed in such manner that the signals picked up by each of these electrodes emanate from a predefined source, e.g. a certain muscle or a certain compartment of a muscle, electromyographic (EMG) signals originating from well-defined sources may be picked up.

Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being would move a part of his body, e.g. a limb or a

part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.

Thus, the system allows the user to move the prosthesis or part of the prosthesis in a highly intuitive way.

Further, by using the system, it will be possible to perform relatively complex movements of a prosthesis or part/parts thereof, as EMG signals may be received from muscles that would normally have been activated by the user of the prosthesis when performing the natural movements of missing body parts. These signals may thus be used to control the corresponding prosthesis parts, whereby the user may perform the desired movements intuitively, i.e. without having to learn to move particular muscle groups in a particular way and/or without having to activate switchover mechanisms etc.

A further advantage of the system is related to environmental control, as the EMG control system may be applied for controlling light, appliances etc., which the user desires to control, e.g. turn on and off. Such an environmental control function may be incorporated in the EMG control system for controlling a prosthesis, whereby the user would be able to control such appliances, for example via wireless control, without actually having to manipulate a control means, e.g. a switch.

According to the preferred embodiment, as stated in claim 13, the one or more dedicated sets of electrodes of the system may be configured for subcutaneous, epimesial or intramuscular use, whereby it is ensured that relatively strong EMG signals from the corresponding muscle will be received by the electrode and that these signals will have a relatively high signal/noise ratio without interference from signals stemming from other sources, e.g. other muscles (cross talk).

Further, as stated in claim 14, said one or more sets of dedicated electrodes of the system may be configured for implantation in a muscle or muscles, whereby the

EMG signals will be received by the electrodes of the system in a relatively powerful form and without cross talk from other sources of EMG signals.

The muscles in which the sets of electrodes are implanted may for example be residual muscles related to a missing part of the body replaced by a prosthesis, e.g. muscles in an arm of a below elbow (BE) amputee. However, the sets of electrodes may be implanted in any residual limb or other muscles as desired in order to improve the EMG signal pattern discriminality. For example, a muscle in a shoulder part of an amputee may provide resourceful EMG signal information relating to the desired movements of for example a hand or an arm, whereby the functionality of the system may be enhanced.

As stated in claim 15, the system may comprise means for transmitting the electromyographic (EMG) signals from said one or more sets of dedicated electrodes to signal processing means by wireless transmission, whereby the disadvantages and/or discomfort associated with signal wires protruding through the skin of the user may be avoided.

According to a preferred embodiment of the system, and as stated in claim 16, the system comprises signal processing means for producing control signals for the artificial limb(s), said signal processing means utilizing a pattern recognition method. By this system, the control signals may be produced in an advantageous manner whereby the control signals may consistently lead to the desired movements of the prosthesis and/or part/parts thereof irrespective of the fact that the EMG signals may vary in form and/or amplitude.

As stated in claim 17, the system may comprise an artificial neural network (ANN) for generating control signals for the artificial limb(s), whereby the pattern recognition method may be performed by the system in a particularly advantageous manner.

Preferably, as stated in claim 18, the system may comprise four or more sets of dedicated electrodes placed in relation to at least four muscles, or combinations of func-

tional distinct muscle compartments, for receipt of electromyographic (EMG) signals. By this system, a sufficient number of distinct EMG signals may be provided in order to achieve at least four different movements of a limb or part/parts thereof.

As stated in claim 19, the system may be utilized to control an artificial arm and/or hand wherein one or more electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus. This system may provide at least four different movements of the artificial arm or part/parts thereof, for example closing and opening of a hand in a palmer grasp mode and closing and opening of a hand in a lateral grasp (also referred to as a key grip) mode.

As stated in claim 20, the system may be utilized to control an artificial arm and/or hand, wherein one or more electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis. By this system, an artificial arm with an even larger degree of freedom may be controlled in a user-friendly and highly intuitive manner by the user. An artificial arm may for example be configured for opening/closing the hand and performing a palmer or a key grip, rotating or flexing the wrist, extending or flexing the fingers and the thumb (selectively) etc., making all these functions controllable by the amputee (the user) in a natural and highly intuitive manner.

The system may, as stated in claim 21, advantageously comprise two or more sets of dedicated electrodes placed in relation to at least one muscle, wherein said two or more dedicated electrodes are placed in relation to different parts of said at least one muscle. Hereby, EMG signals from different parts of the muscle may be picked up by the system. These EMG signals may differ and may be used by the system to achieve an even more complex and detailed pattern of movements performed by a prosthesis such as an artificial limb.

Finally, as stated in claim 22, the system may comprise one or more sets of electroneurographic (ENG) electrodes for receiving electroneurographic (ENG) signals which may be used as complimentary signals for generating control signals.

Hereby, further information concerning a desired movement may be provided and used to control a prosthesis. In cases where EMG signals may not be recorded, for example EMG signals stemming from muscles which are absent, in particular the intrinsic muscles of the hand, it may be possible to record corresponding ENG signals, for example from the trunk nerves in the upper arm. These ENG signals will contain information complimentary to the EMG signals when generating control signals, whereby an improved control system for a prosthesis is provided. The ENG electrodes for recording ENG signals from the nerves may be configured in a number of ways known to a person skilled in the art.

Figures

The invention will be described below with reference to the drawings of which

fig. 1 shows a cross section of the lower part of an arm illustrating the suggested positioning of dedicated electromyographic (EMG) electrodes according to the invention,

fig. 2 shows an example of an electromyographic (EMG) signal picked up by a sets of EMG electrodes according to the invention,

fig. 3 illustrates a system for recording, processing and evaluating EMG signals from a human being, and

fig. 4 illustrates a block diagram, wherein a pattern recognition circuit with artificial neural networks are utilized to control an artificial limb.

Detailed description

Fig. 1 illustrates a cross section of the right forearm of a human being, for example a human being who has lost a hand and perhaps part of the lower arm. The cross sec-

tion shown in fig. 1 thus illustrates the residual muscles in the remaining part of the lower arm.

The cross section might be an image of the arm provided by an MRI (magnetic resonance imaging) scanner, and the MRI technique may also be employed when implanting the electrodes according to the invention.

The view is from distal to proximal with the Dorsal surface at the top and with the Radial surface to the left of the figure. The figure indicates the relevant residual muscles for recording electromyographic (EMG) signals:

Flexor digitorum profundus 1,
Flexor digitorum superficialis 2,
Extensor digitorum 3,
Flexor pollicis longus 4,
Extensor pollicis longus 5,
Supinator 6,
Pronator teres 7,
Flexor carpi radials8,
Flexor carpi ulnaris 9,
Extensor carpi radialis brevis 10,
Extensor carpi radialis longus 11,
Extensor carpi ulnaris 12.

From the figure, it may be observed that several of these muscles are placed relatively deep in the arm and are not directly accessible. EMG signals from these muscles will thus be difficult to obtain with surface electrodes. In particular, Extensor pollicis longus 5, Supinator 6 and Flexor pollicis longus 4 are inaccessible and cannot be recorded by using surface mounted electrodes.

A selection of palmer grip versus key grip can be achieved by analyzing the EMG activity of four muscle groups:

Finger flexors: This can be Flexor digitorum profundus 1 or Flexor digitorum superficialis 2.

Finger extensors: This can be extensor digitorum 3.

Thumb flexor: This can be Flexor pollicis longus 4.

Thumb extensor: This can be Extensor pollicis longus 5.

A selection of the function of wrist movements (flexion; extension; pronation and supination) can be achieved by analyzing the EMG activity of four muscle groups:

Wrist supination: This can be Supinator 6.

Wrist pronation: This can be Pronator teres 7.

Wrist flexion: This can be Flexor carpi radials 8 or Flexor carpi ulnaris 9.

Wrist extension: This can be Extensor carpi radialis brevis 10, Extensor carpi radialis longus 11 or Extensor carpi ulnaris 12.

Electrodes for receiving electromyographic (EMG) signals from the muscles may be implanted in these muscles, for example in special parts of these muscles, where the signals may be picked up in a relatively strong form, with or without only a small amount of cross talk.

The electrodes may be monopolar, bipolar,tripolar etc. The electrodes may be placed percutaneously, whereby the signal wires will have to protrude through the skin of the user. This has some disadvantages such as the risk of infection and the discomfort to the user which makes the use of electrodes, which are totally implanted, preferable.

When totally implanted electrodes are used, the signals may be transmitted for example by telemetry by electromagnetic, optical or other means, to the surface of the arm and/or to the processing means of the signals.

Fig. 2 illustrates an example of a EMG signal picked up from a residual muscle in a lower arm. The signal from the EMG electrode has been processed, e.g. amplified (1000 – 10000), band-pass filtered (10 Hz – 1 kHz) and sampled (2 kHz). Further, the signal has been processed in order to remove DC-offset and motion artifacts (digital high pass, Butterworth order 4, 20 Hz). Finally, the signal has been full-wave rectified and a moving average signal has been provided (over a 25 ms sliding window) before the signal has been processed in order to determine an onset.

This has been done by applying a 200 ms sliding window 21 to the moving average signal. If the number of samples in this 200 ms window 21 exceeds an appropriate threshold value for at least 175 ms (not necessarily consecutively), the first point of this window 21 is labeled as the onset 22. Initial spikes 23 will thus not have any influence on the detection of the onset event 22.

Following the detection of an onset event, a search for an offset event, for example when the number of samples below the appropriate threshold exceeds 150 ms, takes place.

This is only an example of the signal processing to determine onset and offset. Other algorithms may be applied in connection with the invention.

Fig. 3 illustrates a system for recording, processing and evaluating EMG signals from a human being, for example in order to examine the signals from implanted electrodes, and for optimizing the positioning of electrodes, the signal processing means or the control means or in order to train a user of a system according to the invention.

A human being 30 who has lost a hand has had a number of EMG electrodes implanted in the forearm 31. These are connected by means of wires 32 to a signal processing means 33 comprising amplifiers and filters. The output from the processing means 33 is delivered to a data acquisition board and computer 34, where the

signals are stored and/or visualized. Further, the system comprises a computer 35 with a screen, on which an animation target 36 is shown.

The animation target 36 is a hand which may perform different movements, grips, etc., and the amputee 30 is asked to mimic with his phantom hand the animations performed by the hand 36. The signals may be stored by the computer 34, and the recorded signals corresponding to the movements and grips intended by the amputee may be used to configure a system according to the invention. In particular, the system illustrated in fig. 3 may be utilized for training artificial neural networks in order to configure a control system according to the invention and in order to individualize such a system.

Fig 4 illustrates a control system according to the invention wherein artificial neural networks (ANN) are utilized. A prosthesis 41 in the form of an artificial hand 41 is illustrated as the object to be controlled by the system. A number of EMG electrodes 43a – 43n are illustrated, each receiving EMG signals 42a – 42n, respectively. The output signals 44a - 44n are amplified, band-pass filtered and transmitted, for example by telemetry by electromagnetic, optical or other means, to a signal processing means 45, comprising for example additional amplifiers, filters etc. The output 46 from this processing means is led to a pattern recognition circuit 47 comprising for example artificial neural networks, wherein the signals are processed in order to determine which movements and/or grips are desired by the user.

From the pattern recognition circuit 47, a signal is sent to a control circuit 48 containing for example power and control circuits, and finally an output signal is led to the driving means 49 of the artificial hand 41.

In addition to the EMG electrodes 43a – 43n delivering signals 44a – 44n to the signal processing means 45, a number of ENG (electroneurographic) electrodes (not shown) may be utilized in connection with the system, providing additional information of the intended movements.

In this case, the invention has been described in relation to an artificial limb in the form of a hand. Evidently, the invention may be used in relation to prostheses in general, e.g. artificial arms, legs, feet, etc.

Further, the invention can be applied for environmental control in addition to control of prostheses. For example, a user may utilize the system to turn lights on and off, to open and close power-controlled doors, to control communication means, to control input to communication means, e.g. computers, to control vehicles, to control appliances etc.

Patent Claims

1. A method of controlling a prosthesis such as an artificial limb, whereby electromyographic (EMG) signals are used to generate control signals for one or more prostheses such as artificial limbs and whereby the electromyographic (EMG) signals are received by one or more sets of electrodes dedicated to a source of electromyographic (EMG) signals.

2. Method according to claim 1, characterized in that said one or more sets of dedicated electrodes is/are placed subcutaneously, epimesially or intramuscularly.

3. Method according to claim 1 or 2, characterized in that said one or more sets of dedicated electrodes are implanted in a muscle or muscles.

4. Method according to one or more of claims 1 - 3, characterized in that the electromyographic (EMG) signals from said one or more sets of dedicated electrodes are transmitted to signal processing means by wireless transmission.

5. Method according to one or more of claims 1 - 4, characterized in that the electromyographic (EMG) signals from said one or more sets of dedicated electrodes are processed by signal processing means, whereby control signals for the artificial limb(s) are produced, said signal processing means utilizing a pattern recognition method.

6. Method according to one or more of claims 1 - 5, characterized in that the control signals of the artificial limb(s) are generated by utilizing an artificial neural network (ANN).

7. Method according to one or more of claims 1 - 6, characterized in that the electromyographic (EMG) signals are received by four or more sets of

dedicated electrodes placed in relation to at least four muscles or distinct functional muscle compartments.

8. Method according to claim 7, characterized in that the method is utilized to control an artificial arm and/or hand and in that one or more sets of electrodes are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus.

9. Method according to claim 7, characterized in that the method is utilized to control an artificial arm and/or hand and in that one or more electrodes are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis.

10. Method according to one or more of claims 1 - 9, characterized in that two or more sets of dedicated electrodes are placed in relation to at least one muscle, said two or more dedicated electrodes being placed in relation to different parts of said at least one muscle.

11. Method according to one or more of claims 1 - 10, characterized in that electroneurographic (ENG) signals are received by one or more separate sets of ENG-electrodes and that these ENG-signals are used as complimentary signals for generating control signals.

12. A system for controlling a prosthesis, such as an artificial limb, wherein electromyographic (EMG) signals are used to generate control signals for one or more artificial limbs and wherein the system comprises one or more sets of electrodes, each dedicated to a source of electromyographic (EMG) signals for receipt of the electromyographic (EMG) signals.

13. System according to claim 12, characterized in that said one or more sets of dedicated electrodes is/are configured for subcutaneous, epimesial or intra-muscular placing.

14. System according to claim 12 or 13, characterized in that said one or more sets of dedicated electrodes is/are configured for an implantation in a muscle or muscles.

15. System according to one or more of claims 12 - 14, characterized in that the system comprises means for transmitting the electromyographic (EMG) signals from said one or more sets of dedicated electrodes to signal processing means by wireless transmission.

16. System according to one or more of claims 12 - 15, characterized in that the system comprises signal processing means for producing control signals for the artificial limb(s), said signal processing means utilizing a pattern recognition method.

17. System according to one or more of claims 12 - 16, characterized in that the system comprises an artificial neural network (ANN) for generating control signals for the artificial limb(s).

18. System according to one or more of claims 12 - 17, characterized in that the system comprises four or more sets of dedicated electrodes placed in relation to at least four muscles or functional distinct muscle compartments for receipt of electromyographic (EMG) signals.

19. System according to claim 18, characterized in that the system is utilized to control an artificial arm and/or hand wherein one or more sets of electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus.

20. System according to claim 18, characterized in that the system is utilized to control an artificial arm and/or hand and in that one or more sets of electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis.

21. System according to one or more of claims 12 - 20, characterized in that the system comprises two or more sets of dedicated electrodes placed in relation to at least one muscle, and in that said two or more sets of dedicated electrodes is/are placed in relation to different parts of said at least one muscle.

22. Method according to one or more of claims 12 - 21, characterized in that the system comprises one or more sets of electroneurographic (ENG) electrodes for receiving electroneurographic (ENG) signals and in that these ENG-signals are used as complimentary signals for generating control signals.

Abstract:

A method and a system for controlling a prosthesis such as an artificial limb. Electromyographic (EMG) signals are used to generate control signals for one or more prostheses such as artificial limbs. The electromyographic (EMG) signals are received by one or more sets of electrodes dedicated to a source of electromyographic (EMG) signals.

By using dedicated electrodes, electromyographic (EMG) signals originating from well-defined sources may be picked up. Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being would move a part of his body, e.g. a limb or a part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.

(Fig. 4)

3/prts

SUBSTITUTE SPECIFICATION (CLEAN VERSION)

EMG CONTROL OF PROSTHESIS

FIELD OF THE INVENTION

The invention relates to a method and a system for controlling prostheses such as artificial limbs.

DESCRIPTION OF RELATED ART

The use of prostheses such as artificial limbs, e.g. hands, arms, legs, feet etc. for human beings who have lost a limb, is well-known.

Further, it is known that such artificial limbs may be constructed to provide (limited) movement of the limb in relation to the user or to provide movement between two parts of the limb, for example the turning of an artificial hand in relation to a corresponding artificial arm. These movements, which may be performed with only one or two degrees of freedom, may be body-powered, be powered electrically or controlled by special control arrangements which can be activated by the user, i.e. the wearer of the prosthesis.

Great efforts have been made to develop a user-friendly way of controlling the movement of artificial limbs. Thus, the use of electromyographic signals, also referred to as EMG signals in the following, have been utilized in prior-art to control prostheses or artificial limbs. In prior-art, these signals stemming from muscles which are activated, e.g. contracted or extended, have been picked up by contact electrodes, placed on the skin of a human being in places where residual muscles are present, e.g. in proximity of residual muscles. As one or more of these residual muscles is/are activated by the human being, EMG signals are generated. These electrical signals are picked up by contact electrodes and can be used as input to a control circuit for initiating movement of an artificial limb.

However, the contact electrodes will usually be placed for example on opposing sides of a lower arm or in such a manner that each electrode will pick up EMG signals from more than one muscle, i.e. a group of muscles. However, the signals picked up by these contact electrodes will still be able to provide a sufficient basis for controlling movements with one degree of freedom, for example the opening and closing of a hand in a palmer grasp mode, as the group of muscles on one side of the lower arm will provide a detectable signal of movement in one direction, for example closing of the hand, while the group of muscles on the other side of the lower arm will provide a detectable signal of movement in the other direction, for example opening of the hand. The user of such a prosthesis thus has to learn that once a certain group of muscles is activated, a palmer grip will be performed, and that the palmer grip will be relaxed and the hand will open when a certain other group of muscles is activated.

This has the disadvantage that some sort of training is required before the use of the prosthesis may be mastered by the user. Further, the movements that may be performed by the prosthesis are limited to relatively simple movements, e.g. opening and closing of a hand. However, it will also be possible to configure a prosthesis capable of performing more than one simple movement by having a switch-over function, for example a switch, which may be activated by the user, whereby the prosthesis may perform another movement, for example a pinch grip or a rotation of a wrist. This second movement will also be triggered by EMG signals from the same muscle groups as the first movement, and the activation by the user will thus be complicated and awkward, and the two different movements cannot be performed simultaneously.

The use of more than two sets of contact electrodes, i.e. electrodes applied to the skin of the user, for receiving EMG signals from different muscles or muscle groups will be difficult if not impossible in practice, as two contact electrodes placed for example on the same side of a lower arm will inevitably receive the same EMG signals emitted by the same muscles or muscle groups (cross talk). Consequently, it will be difficult to make a distinction between the signals received from these two contact electrodes and thus make control of two different movements by these signals impossible. Even if it were possible to place two contact electrodes on the same side of an

arm in such a manner that the signals picked up by these contact electrodes would be distinctly different, i.e. not involving substantial cross talk, it would be necessary to teach the user to activate more than two muscles or muscle groups independently of each other in order to be able to achieve motions of the artificial limb with more than one degree of freedom. Hence, this would involve even more extensive training before the user would be able to master the use of the prosthesis satisfactorily.

Thus, it is an object of the present invention to provide a method and a system for controlling a prosthesis such as an artificial limb, whereby the movement of the prosthesis and/or parts thereof may be performed in a user-friendly manner by the user.

Another object of the invention is to provide a method and a system for controlling a prosthesis such as an artificial limb, whereby the movements of the prosthesis and/or part/parts thereof may be performed in a highly intuitive manner, e.g. a manner, which will be natural to the user.

It is a further object of the invention to provide a method and a system whereby relatively complex movements may be performed by the prosthesis and/or parts thereof.

These and other objects are achieved by the invention.

BREIF SUMMARY OF THE INVENTION

The invention relates to a method of controlling a prosthesis such as an artificial limb, whereby electromyographic (EMG) signals are used to generate control signals for one or more prostheses such as artificial limbs, and whereby the electromyographic (EMG) signals are received by one or more sets of electrodes dedicated to a source of electromyographic (EMG) signals.

By using dedicated electrodes, i.e. electrodes designed and placed in such manner that the signals picked up by each of these sets of electrodes emanate from a predefined source, e.g. a certain muscle or a certain compartment within the muscle, elec-

tromyographic (EMG) signals originating from well-defined sources may be picked up.

Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being should desire to move a part of his body, e.g. a limb or a part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.

Thus, the prosthesis or part of the prosthesis may be moved by the user in a highly intuitive way.

Further, it will be possible to perform relatively complex movements of a prosthesis or part/parts thereof as EMG signals may be received from muscles which would normally have been activated by the user of the prosthesis when performing the natural movements of the missing body part(s). These signals may thus be used to control the corresponding prosthesis parts, whereby the user may perform the desired movements intuitively, i.e. without having to learn to move a particular muscle group(s) in a particular way and/or without having to activate switch-over mechanisms etc.

A further advantage of the invention is related to environmental control, as the EMG control method may be applied for controlling light, appliances etc, which the user desires to control, e.g. turn on and off. Such an environmental control function may be configured in relation to the EMG control method for controlling a prosthesis, whereby the user would be able to control such appliances, for example via wireless control, without actually having to manipulate a control means, e.g. a switch.

The electrodes are constituted by sets of electrodes. In order to pick up an electrical signal, e.g. an electrical potential, a measurement or detection has to be made in at least two (spatially) different places in order to achieve a potential difference. Thus, at least two electrodes constitute a set of electrodes. Evidently, such a set of electrodes may be configured as a unit, whereby the distance between the two measuring

or detection points of the set of electrodes is predefined and kept at a constant by the unit, or the electrodes may be separate parts.

The one or more sets of dedicated electrodes may preferably be placed subcutaneously, epimesially or intramuscularly, whereby it is ensured that relatively strong EMG signals from the corresponding muscle will be received by the electrode and that these signals will not be influenced by signals stemming from other sources, e.g. other muscles (cross talk).

Further, said one or more sets of dedicated electrodes may be implanted in a muscle or muscles whereby the EMG signals will be received by the electrodes in a relatively powerful form without any cross talk from other sources of EMG signals.

The muscles, in which the sets of electrodes are implanted, may for example be residual muscles related to a missing part of the body replaced by a prosthesis, e.g. muscles in an arm of a below elbow (BE) amputee. However, the sets of electrodes may be implanted in any residual limb or other muscles as desired in order to improve the EMG signal pattern discriminality. For example, a muscle in a shoulder part of an amputee may provide resourceful EMG signal information relating to the desired movements of for example a hand or an arm.

Preferably the electromyographic (EMG) signals from said one or more sets of dedicated electrodes may be transmitted to signal processing means by wireless transmission, whereby the disadvantages and/or discomfort associated with signal wires protruding through the skin of the user may be avoided.

In a preferred embodiment the electromyographic (EMG) signals from said one or more sets of dedicated electrodes are processed by signal processing means, whereby control signals for the artificial limb(s) are produced, said signal processing means utilizing a pattern recognition method. Hereby, the control signals may be produced in an advantageous manner and the control signals may consistently lead to the de-

sired movements of the prosthesis and/or part/parts thereof irrespective of the fact that the EMG signals may vary in form and/or amplitude.

The control signals of the artificial limb(s) may be generated by utilizing an artificial neural network (ANN), whereby the pattern recognition method may be performed in a particularly advantageous manner.

The electromyographic (EMG) signals may preferably be received by four or more sets of dedicated electrodes, located in relation to at least four muscles, or combinations of distinct functional muscle compartments, whereby a sufficient number of distinct EMG signals may be provided in order to achieve at least four different movements of a limb or part/parts thereof.

The method may be utilized to control an artificial arm and/or hand, whereby one or more sets of electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus. This may provide at least four different movements of the artificial arm or part/parts thereof, for example closing and opening of a hand in a palmer grasp mode and closing and opening of a hand in a lateral grasp (also referred to as a key grip) mode.

The method may be utilized to control an artificial arm and/or hand, whereby one or more sets of electrodes are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis. Hereby, an artificial arm with an even larger degree of freedom may be controlled in a user-friendly and highly intuitive manner by the user. An artificial arm may for example be configured for opening/closing the hand and performing a palmer or a key grip, rotating or flexing the wrist, extending or bending the fingers and the thumb (selectively) etc., making all these functions controllable by the amputee (the user) in a natural and highly intuitive manner.

Two or more dedicated sets of electrodes may be placed in relation to at least one muscle, said two or more sets of dedicated electrodes being placed in relation to different parts of said at least one muscle. Hereby, EMG signals from different parts of the muscle may be picked up. These EMG signals may differ and may be used to achieve greater reliability and/or even more complex and detailed patterns of movements performed by a prosthesis such as an artificial limb.

Finally, electroneurographic (ENG) signals may be received by one or more separate sets of ENG-electrodes and these ENG-signals may be used as complimentary signals for generating control signals. Hereby, further information concerning a desired movement may be provided and used to control a prosthesis. In cases where EMG signals may not be recorded, for example EMG signals stemming from muscles, which are absent, in particular the intrinsic muscles of the hand, it may be possible to record corresponding ENG signals, for example from the trunk nerves in the upper arm. These ENG signals will contain information complimentary to the EMG signals, whereby improved control of a prosthesis is provided. The ENG signals from the nerves may be provided in a number of ways known to a person skilled in the art.

The invention also relates to a system for controlling a prosthesis, such as an artificial limb. Electromyographic (EMG) signals are used to generate control signals for one or more artificial limbs and the system comprises one or more sets of dedicated electrodes, each placed in relation to a muscle, for receipt of the electromyographic (EMG) signals.

By using dedicated electrodes, i.e. electrodes designed and placed in such manner that the signals picked up by each of these electrodes emanate from a predefined source, e.g. a certain muscle or a certain compartment of a muscle, electromyographic (EMG) signals originating from well-defined sources may be picked up.

Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being would move a part of his body, e.g. a limb or a

part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.

Thus, the system allows the user to move the prosthesis or part of the prosthesis in a highly intuitive way.

Further, by using the system, it will be possible to perform relatively complex movements of a prosthesis or part/parts thereof, as EMG signals may be received from muscles that would normally have been activated by the user of the prosthesis when performing the natural movements of missing body parts. These signals may thus be used to control the corresponding prosthesis parts, whereby the user may perform the desired movements intuitively, i.e. without having to learn to move particular muscle groups in a particular way and/or without having to activate switchover mechanisms etc.

A further advantage of the system is related to environmental control, as the EMG control system may be applied for controlling light, appliances etc., which the user desires to control, e.g. turn on and off. Such an environmental control function may be incorporated in the EMG control system for controlling a prosthesis, whereby the user would be able to control such appliances, for example via wireless control, without actually having to manipulate a control means, e.g. a switch.

According to the preferred embodiment, the one or more dedicated sets of electrodes of the system may be configured for subcutaneous, epimesial or intramuscular use, whereby it is ensured that relatively strong EMG signals from the corresponding muscle will be received by the electrode and that these signals will have a relatively high signal/noise ratio without interference from signals stemming from other sources, e.g. other muscles (cross talk).

Further, said one or more sets of dedicated electrodes of the system may be configured for implantation in a muscle or muscles, whereby the EMG signals will be re-

ceived by the electrodes of the system in a relatively powerful form and without cross talk from other sources of EMG signals.

The muscles in which the sets of electrodes are implanted may for example be residual muscles related to a missing part of the body replaced by a prosthesis, e.g. muscles in an arm of a below elbow (BE) amputee. However, the sets of electrodes may be implanted in any residual limb or other muscles as desired in order to improve the EMG signal pattern discriminality. For example, a muscle in a shoulder part of an amputee may provide resourceful EMG signal information relating to the desired movements of for example a hand or an arm, whereby the functionality of the system may be enhanced.

The system may comprise means for transmitting the electromyographic (EMG) signals from said one or more sets of dedicated electrodes to signal processing means by wireless transmission, whereby the disadvantages and/or discomfort associated with signal wires protruding through the skin of the user may be avoided.

According to a preferred embodiment of the system, the system comprises signal processing means for producing control signals for the artificial limb(s), said signal processing means utilizing a pattern recognition method. By this system, the control signals may be produced in an advantageous manner whereby the control signals may consistently lead to the desired movements of the prosthesis and/or part/parts thereof irrespective of the fact that the EMG signals may vary in form and/or amplitude.

The system may comprise an artificial neural network (ANN) for generating control signals for the artificial limb(s), whereby the pattern recognition method may be performed by the system in a particularly advantageous manner.

Preferably, the system may comprise four or more sets of dedicated electrodes placed in relation to at least four muscles, or combinations of functional distinct muscle compartments, for receipt of electromyographic (EMG) signals. By this system, a

sufficient number of distinct EMG signals may be provided in order to achieve at least four different movements of a limb or part/parts thereof.

The system may be utilized to control an artificial arm and/or hand wherein one or more electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus. This system may provide at least four different movements of the artificial arm or part/parts thereof, for example closing and opening of a hand in a palmer grasp mode and closing and opening of a hand in a lateral grasp (also referred to as a key grip) mode.

The system may be utilized to control an artificial arm and/or hand, wherein one or more electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis. By this system, an artificial arm with an even larger degree of freedom may be controlled in a user-friendly and highly intuitive manner by the user. An artificial arm may for example be configured for opening/closing the hand and performing a palmer or a key grip, rotating or flexing the wrist, extending or flexing the fingers and the thumb (selectively) etc., making all these functions controllable by the amputee (the user) in a natural and highly intuitive manner.

The system may advantageously comprise two or more sets of dedicated electrodes placed in relation to at least one muscle, wherein said two or more dedicated electrodes are placed in relation to different parts of said at least one muscle. Hereby, EMG signals from different parts of the muscle may be picked up by the system. These EMG signals may differ and may be used by the system to achieve an even more complex and detailed pattern of movements performed by a prosthesis such as an artificial limb.

Finally, the system may comprise one or more sets of electroneurographic (ENG) electrodes for receiving electroneurographic (ENG) signals which may be used as complimentary signals for generating control signals.

Hereby, further information concerning a desired movement may be provided and used to control a prosthesis. In cases where EMG signals may not be recorded, for example EMG signals stemming from muscles which are absent, in particular the intrinsic muscles of the hand, it may be possible to record corresponding ENG signals, for example from the trunk nerves in the upper arm. These ENG signals will contain information complimentary to the EMG signals when generating control signals, whereby an improved control system for a prosthesis is provided. The ENG electrodes for recording ENG signals from the nerves may be configured in a number of ways known to a person skilled in the art.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The invention will be described below with reference to the drawings in which

Fig. 1 shows a cross section of the lower part of an arm illustrating the suggested positioning of dedicated electromyographic (EMG) electrodes according to the invention,

Fig. 2 shows an example of an electromyographic (EMG) signal picked up by a set of EMG electrodes according to the invention,

Fig. 3 illustrates a system for recording, processing and evaluating EMG signals from a human being, and

Fig. 4 illustrates a block diagram, wherein a pattern recognition circuit with artificial neural networks are utilized to control an artificial limb.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 illustrates a cross section of the right forearm of a human being, for example a human being who has lost a hand and perhaps part of the lower arm. The cross sec-

tion shown in Fig. 1 thus illustrates the residual muscles in the remaining part of the lower arm.

The cross section might be an image of the arm provided by an MRI (magnetic resonance imaging) scanner, and the MRI technique may also be employed when implanting the electrodes according to the invention.

The view is from distal to proximal with the Dorsal surface at the top and with the Radial surface to the left of the figure. The figure indicates the relevant residual muscles for recording electromyographic (EMG) signals:

Flexor digitorum profundus 1,
Flexor digitorum superficialis 2,
Extensor digitorum 3,
Flexor pollicis longus 4,
Extensor pollicis longus 5,
Supinator 6,
Pronator teres 7,
Flexor carpi radials8,
Flexor carpi ulnaris 9,
Extensor carpi radialis brevis 10,
Extensor carpi radialis longus 11,
Extensor carpi ulnaris 12.

From the figure, it may be observed that several of these muscles are placed relatively deep in the arm and are not directly accessible. EMG signals from these muscles will thus be difficult to obtain with surface electrodes. In particular, Extensor pollicis longus 5, Supinator 6 and Flexor pollicis longus 4 are inaccessible and cannot be recorded by using surface mounted electrodes.

A selection of palmer grip versus key grip can be achieved by analyzing the EMG activity of four muscle groups:

Finger flexors: This can be Flexor digitorum profundus 1 or Flexor digitorum superficialis 2.

Finger extensors: This can be extensor digitorum 3.

Thumb flexor: This can be Flexor pollicis longus 4.

Thumb extensor: This can be Extensor pollicis longus 5.

A selection of the function of wrist movements (flexion; extension; pronation and supination) can be achieved by analyzing the EMG activity of four muscle groups:

Wrist supination: This can be Supinator 6.

Wrist pronation: This can be Pronator teres 7.

Wrist flexion: This can be Flexor carpi radials 8 or Flexor carpi ulnaris 9.

Wrist extension: This can be Extensor carpi radialis brevis 10, Extensor carpi radialis longus 11 or Extensor carpi ulnaris 12.

Electrodes for receiving electromyographic (EMG) signals from the muscles may be implanted in these muscles, for example in special parts of these muscles, where the signals may be picked up in a relatively strong form, with or without only a small amount of cross talk.

The electrodes may be monopolar, bipolar,tripolar etc. The electrodes may be placed percutaneously, whereby the signal wires will have to protrude through the skin of the user. This has some disadvantages such as the risk of infection and the discomfort to the user which makes the use of electrodes, which are totally implanted, preferable.

When totally implanted electrodes are used, the signals may be transmitted for example by telemetry by electromagnetic, optical or other means, to the surface of the arm and/or to the processing means of the signals.

Fig. 2 illustrates an example of a EMG signal picked up from a residual muscle in a lower arm. The signal from the EMG electrode has been processed, e.g. amplified (1000 – 10000), band-pass filtered (10 Hz – 1 kHz) and sampled (2 kHz). Further, the signal has been processed in order to remove DC-offset and motion artifacts (digital high pass, Butterworth order 4, 20 Hz). Finally, the signal has been full-wave rectified and a moving average signal has been provided (over a 25 ms sliding window) before the signal has been processed in order to determine an onset.

This has been done by applying a 200 ms sliding window 21 to the moving average signal. If the number of samples in this 200 ms window 21 exceeds an appropriate threshold value for at least 175 ms (not necessarily consecutively), the first point of this window 21 is labeled as the onset 22. Initial spikes 23 will thus not have any influence on the detection of the onset event 22.

Following the detection of an onset event, a search for an offset event, for example when the number of samples below the appropriate threshold exceeds 150 ms, takes place.

This is only an example of the signal processing to determine onset and offset. Other algorithms may be applied in connection with the invention.

Fig. 3 illustrates a system for recording, processing and evaluating EMG signals from a human being, for example in order to examine the signals from implanted electrodes, and for optimizing the positioning of electrodes, the signal processing means or the control means or in order to train a user of a system according to the invention.

A human being 30 who has lost a hand has had a number of EMG electrodes implanted in the forearm 31. These are connected by means of wires 32 to a signal processing means 33 comprising amplifiers and filters. The output from the processing means 33 is delivered to a data acquisition board and computer 34, where the

signals are stored and/or visualized. Further, the system comprises a computer 35 with a screen, on which an animation target 36 is shown.

The animation target 36 is a hand which may perform different movements, grips, etc., and the amputee 30 is asked to mimic with his phantom hand the animations performed by the hand 36. The signals may be stored by the computer 34, and the recorded signals corresponding to the movements and grips intended by the amputee may be used to configure a system according to the invention. In particular, the system illustrated in fig. 3 may be utilized for training artificial neural networks in order to configure a control system according to the invention and in order to individualize such a system.

Fig 4 illustrates a control system according to the invention wherein artificial neural networks (ANN) are utilized. A prosthesis 41 in the form of an artificial hand 41 is illustrated as the object to be controlled by the system. A number of EMG electrodes 43a – 43n are illustrated, each receiving EMG signals 42a – 42n, respectively. The output signals 44a - 44n are amplified, band-pass filtered and transmitted, for example by telemetry by electromagnetic, optical or other means, to a signal processing means 45, comprising for example additional amplifiers, filters etc. The output 46 from this processing means is led to a pattern recognition circuit 47 comprising for example artificial neural networks, wherein the signals are processed in order to determine which movements and/or grips are desired by the user.

From the pattern recognition circuit 47, a signal is sent to a control circuit 48 containing for example power and control circuits, and finally an output signal is led to the driving means 49 of the artificial hand 41.

In addition to the EMG electrodes 43a – 43n delivering signals 44a – 44n to the signal processing means 45, a number of ENG (electroneurographic) electrodes (not shown) may be utilized in connection with the system, providing additional information of the intended movements.

In this case, the invention has been described in relation to an artificial limb in the form of a hand. Evidently, the invention may be used in relation to prostheses in general, e.g. artificial arms, legs, feet, etc.

Further, the invention can be applied for environmental control in addition to control of prostheses. For example, a user may utilize the system to turn lights on and off, to open and close power-controlled doors, to control communication means, to control input to communication means, e.g. computers, to control vehicles, to control appliances etc.

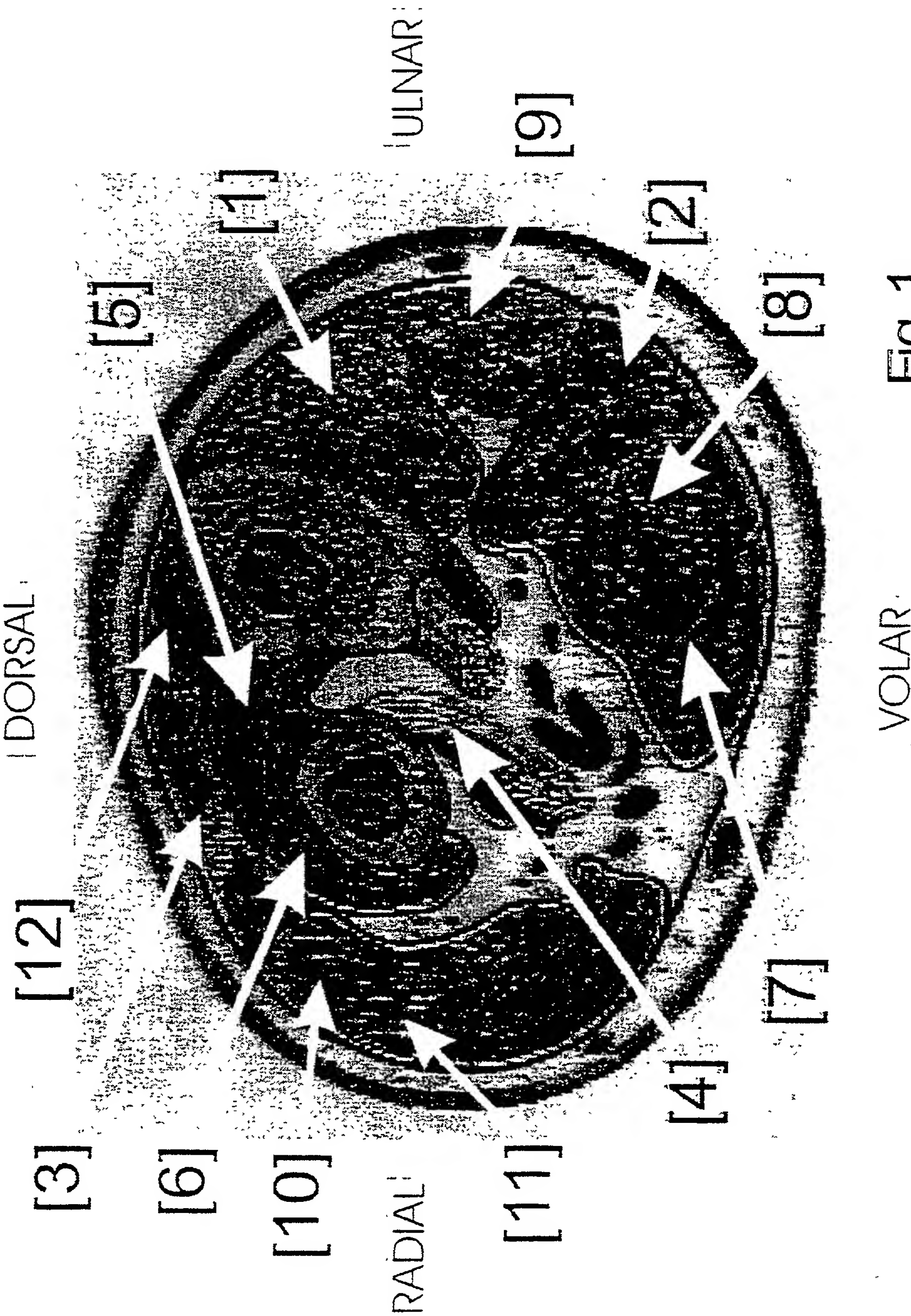

Fig. 1

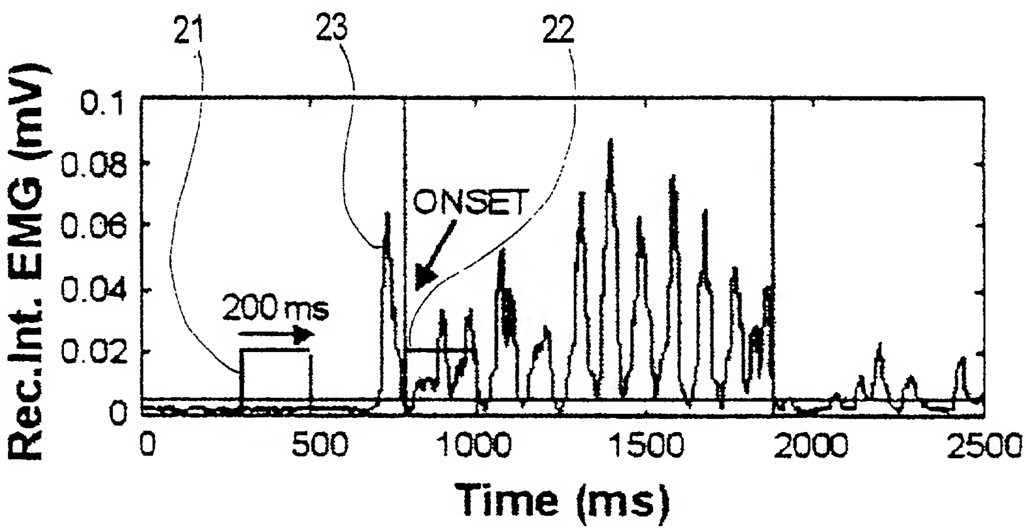
21
23
22
Rec.Int. EMG (mV)
0.1
0.08
0.06
0.04
0.02
0
ONSET
200 ms
0
500
1000
1500
2000
2500
Time (ms)

Fig. 2

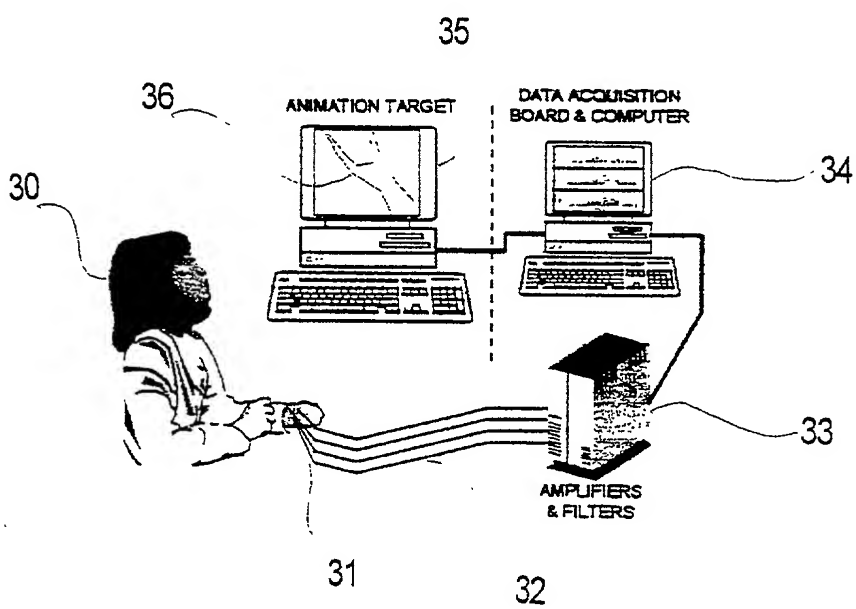
35
36
ANIMATION TARGET
DATA ACQUISITION
BOARD & COMPUTER
34
30
33
AMPLIFIERS
& FILTERS
31
32

Fig. 3

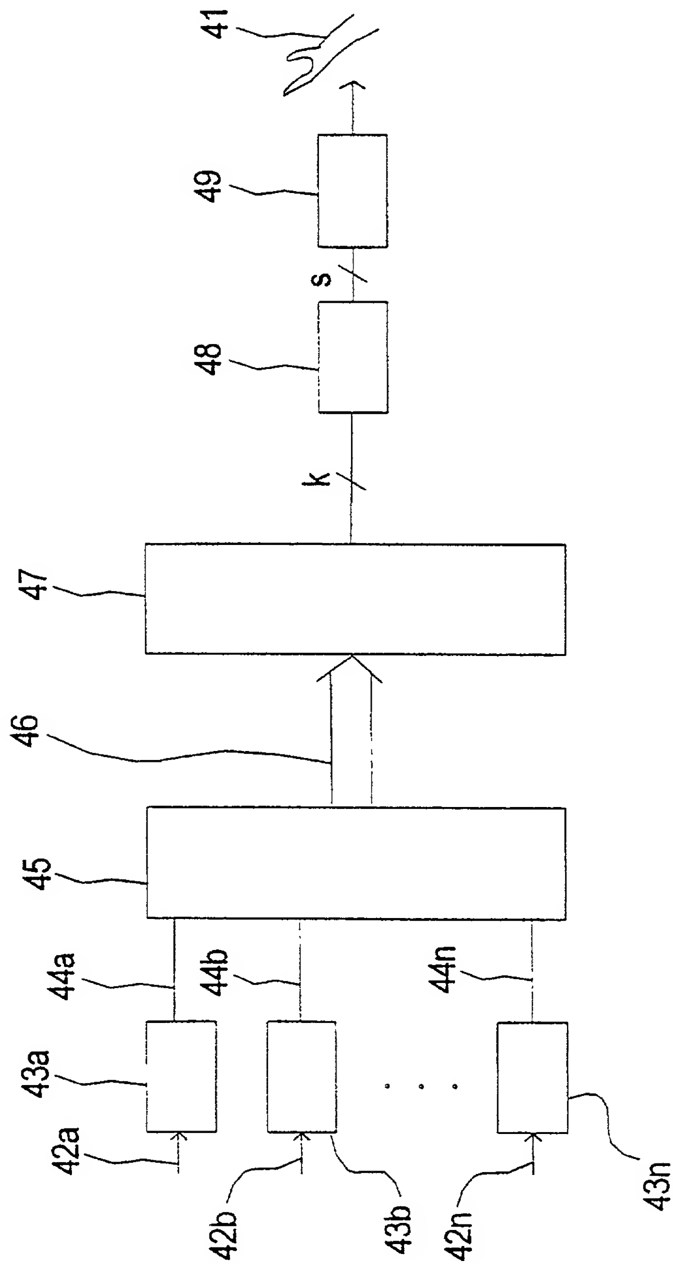

Fig. 4

10/069559
JC13 Rec'd PCT/PTO 20 FEB 2002

SUBSTITUTE SPECIFICATION (MARKED-UP VERSION)

EMG CONTROL OF PROSTHESIS

~~Field of the invention~~FIELD OF THE INVENTION

The invention relates to a method and a system for controlling prostheses such as artificial limbs~~ according to claim 1 and claim 12, respectively~~.

~~Background of the invention~~DESCRIPTION OF RELATED ART

The use of prostheses such as artificial limbs, e.g. hands, arms, legs, feet etc. for human beings who have lost a limb, is well-known.

Further, it is known that such artificial limbs may be constructed to provide (limited) movement of the limb in relation to the user or to provide movement between two parts of the limb, for example the turning of an artificial hand in relation to a corresponding artificial arm. These movements, which may be performed with only one or two degrees of freedom, may be body-powered, be powered electrically or controlled by special control arrangements which can be activated by the user, i.e. the wearer of the prosthesis.

Great efforts have been made to develop a user-friendly way of controlling the movement of artificial limbs. Thus, the use of electromyographic signals, also referred to as EMG signals in the following, have been utilized in prior-art to control prostheses or artificial limbs. In prior-art, these signals stemming from muscles which are activated, e.g. contracted or extended, have been picked up by contact electrodes, placed on the skin of a human being in places where residual muscles are present, e.g. in proximity of residual muscles. As one or more of these residual muscles is/are activated by the human being, EMG signals are generated. These electrical signals are picked up by contact electrodes and can be used as input to a control circuit for initiating movement of an artificial limb.

However, the contact electrodes will usually be placed for example on opposing sides of a lower arm or in such a manner that each electrode will pick up EMG signals from more than one muscle, i.e. a group of muscles. However, the signals picked up by these contact electrodes will still be able to provide a sufficient basis for controlling movements with one degree of freedom, for example the opening and closing of a hand in a palmer grasp mode, as the group of muscles on one side of the lower arm will provide a detectable signal of movement in one direction, for example closing of the hand, while the group of muscles on the other side of the lower arm will provide a detectable signal of movement in the other direction, for example opening of the hand. The user of such a prosthesis thus has to learn that once a certain group of muscles is activated, a palmer grip will be performed, and that the palmer grip will be relaxed and the hand will open when a certain other group of muscles is activated.

This has the disadvantage that some sort of training is required before the use of the prosthesis may be mastered by the user. Further, the movements that may be performed by the prosthesis are limited to relatively simple movements, e.g. opening and closing of a hand. However, it will also be possible to configure a prosthesis capable of performing more than one simple movement by having a switch-over function, for example a switch, which may be activated by the user, whereby the prosthesis may perform another movement, for example a pinch grip or a rotation of a wrist. This second movement will also be triggered by EMG signals from the same muscle groups as the first movement, and the activation by the user will thus be complicated and awkward, and the two different movements cannot be performed simultaneously.

The use of more than two sets of contact electrodes, i.e. electrodes applied to the skin of the user, for receiving EMG signals from different muscles or muscle groups will be difficult if not impossible in practice, as two contact electrodes placed for example on the same side of a lower arm will inevitably receive the same EMG signals emitted by the same muscles or muscle groups (cross talk). Consequently, it will be difficult to make a distinction between the signals received from these two contact electrodes and thus make control of two different movements by these signals impossible. Even if it were possible to place two contact electrodes on the same side of an arm in such a manner that the signals picked up by these contact electrodes

arm in such a manner that the signals picked up by these contact electrodes would be distinctly different, i.e. not involving substantial cross talk, it would be necessary to teach the user to activate more than two muscles or muscle groups independently of each other in order to be able to achieve motions of the artificial limb with more than one degree of freedom. Hence, this would involve even more extensive training before the user would be able to master the use of the prosthesis satisfactorily.

Thus, it is an object of the present invention to provide a method and a system for controlling a prosthesis such as an artificial limb, whereby the movement of the prosthesis and/or parts thereof may be performed in a user-friendly manner by the user.

Another object of the invention is to provide a method and a system for controlling a prosthesis such as an artificial limb, whereby the movements of the prosthesis and/or part/parts thereof may be performed in a highly intuitive manner, e.g. a manner, which will be natural to the user.

It is a further object of the invention to provide a method and a system whereby relatively complex movements may be performed by the prosthesis and/or parts thereof.

These and other objects are achieved by the invention.

~~**Summary of the invention**~~BREIF SUMMARY OF THE INVENTION

~~As stated in claim 1, t~~The invention relates to a method of controlling a prosthesis such as an artificial limb, whereby electromyographic (EMG) signals are used to generate control signals for one or more prostheses such as artificial limbs, and whereby the electromyographic (EMG) signals are received by one or more sets of electrodes dedicated to a source of electromyographic (EMG) signals.

By using dedicated electrodes, i.e. electrodes designed and placed in such manner that the signals picked up by each of these sets of electrodes emanate from a predefined source, e.g. a certain muscle or a certain compartment within the muscle, elec-

tromyographic (EMG) signals originating from well-defined sources may be picked up.

Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being should desire to move a part of his body, e.g. a limb or a part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.

Thus, the prosthesis or part of the prosthesis may be moved by the user in a highly intuitive way.

Further, it will be possible to perform relatively complex movements of a prosthesis or part/parts thereof as EMG signals may be received from muscles which would normally have been activated by the user of the prosthesis when performing the natural movements of the missing body part(s). These signals may thus be used to control the corresponding prosthesis parts, whereby the user may perform the desired movements intuitively, i.e. without having to learn to move a particular muscle group(s) in a particular way and/or without having to activate switch-over mechanisms etc.

A further advantage of the invention is related to environmental control, as the EMG control method may be applied for controlling light, appliances etc, which the user desires to control, e.g. turn on and off. Such an environmental control function may be configured in relation to the EMG control method for controlling a prosthesis, whereby the user would be able to control such appliances, for example via wireless control, without actually having to manipulate a control means, e.g. a switch.

The electrodes are constituted by sets of electrodes. In order to pick up an electrical signal, e.g. an electrical potential, a measurement or detection has to be made in at least two (spatially) different places in order to achieve a potential difference. Thus, at least two electrodes constitute a set of electrodes. Evidently, such a set of electrodes may be configured as a unit, whereby the distance between the two measuring

or detection points of the set of electrodes is predefined and kept at a constant by the unit, or the electrodes may be separate parts.

The one or more sets of dedicated electrodes may preferably~~, as stated in claim 2,~~ be placed subcutaneously, epimesially or intramuscularly, whereby it is ensured that relatively strong EMG signals from the corresponding muscle will be received by the electrode and that these signals will not be influenced by signals stemming from other sources, e.g. other muscles (cross talk).

Further, said one or more sets of dedicated electrodes may be implanted in a muscle or muscles~~, as stated in claim 3,~~ whereby the EMG signals will be received by the electrodes in a relatively powerful form without any cross talk from other sources of EMG signals.

The muscles, in which the sets of electrodes are implanted, may for example be residual muscles related to a missing part of the body replaced by a prosthesis, e.g. muscles in an arm of a below elbow (BE) amputee. However, the sets of electrodes may be implanted in any residual limb or other muscles as desired in order to improve the EMG signal pattern discriminality. For example, a muscle in a shoulder part of an amputee may provide resourceful EMG signal information relating to the desired movements of for example a hand or an arm.

Preferably~~, as stated in claim 4,~~ the electromyographic (EMG) signals from said one or more sets of dedicated electrodes may be transmitted to signal processing means by wireless transmission, whereby the disadvantages and/or discomfort associated with signal wires protruding through the skin of the user may be avoided.

In a preferred embodiment~~, as stated in claim 5,~~ the electromyographic (EMG) signals from said one or more sets of dedicated electrodes are processed by signal processing means, whereby control signals for the artificial limb(s) are produced, said signal processing means utilizing a pattern recognition method. Hereby, the control signals may be produced in an advantageous manner and the control signals may

consistently lead to the desired movements of the prosthesis and/or part/parts thereof irrespective of the fact that the EMG signals may vary in form and/or amplitude.

~~As stated in claim 6, t~~The control signals of the artificial limb(s) may be generated by utilizing an artificial neural network (ANN), whereby the pattern recognition method may be performed in a particularly advantageous manner.

~~As stated in claim 7, t~~The electromyographic (EMG) signals may preferably be received by four or more sets of dedicated electrodes, located in relation to at least four muscles, or combinations of distinct functional muscle compartments, whereby a sufficient number of distinct EMG signals may be provided in order to achieve at least four different movements of a limb or part/parts thereof.

~~As stated in claim 8, t~~The method may be utilized to control an artificial arm and/or hand, whereby one or more sets of electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus. This may provide at least four different movements of the artificial arm or part/parts thereof, for example closing and opening of a hand in a palmer grasp mode and closing and opening of a hand in a lateral grasp (also referred to as a key grip) mode.

~~As stated in claim 9, t~~The method may be utilized to control an artificial arm and/or hand, whereby one or more sets of electrodes are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis. Hereby, an artificial arm with an even larger degree of freedom may be controlled in a user-friendly and highly intuitive manner by the user. An artificial arm may for example be configured for opening/closing the hand and performing a palmer or a key grip, rotating or flexing the wrist, extending or bending the fingers and the thumb (selectively) etc., making all these functions controllable by the amputee (the user) in a natural and highly intuitive manner.

~~As stated in claim 10, t~~Two or more dedicated sets of electrodes may be placed in relation to at least one muscle, said two or more sets of dedicated electrodes being placed in relation to different parts of said at least one muscle. Hereby, EMG signals from different parts of the muscle may be picked up. These EMG signals may differ and may be used to achieve greater reliability and/or even more complex and detailed patterns of movements performed by a prosthesis such as an artificial limb.

Finally, ~~as stated in claim 11,~~ electroneurographic (ENG) signals may be received by one or more separate sets of ENG-electrodes and these ENG-signals may be used as complimentary signals for generating control signals. Hereby, further information concerning a desired movement may be provided and used to control a prosthesis. In cases where EMG signals may not be recorded, for example EMG signals stemming from muscles, which are absent, in particular the intrinsic muscles of the hand, it may be possible to record corresponding ENG signals, for example from the trunk nerves in the upper arm. These ENG signals will contain information complimentary to the EMG signals, whereby improved control of a prosthesis is provided. The ENG signals from the nerves may be provided in a number of ways known to a person skilled in the art.

The invention also relates to a system for controlling a prosthesis, such as an artificial limb~~, as claimed in claim 12~~. ~~According to claim 12, e~~Electromyographic (EMG) signals are used to generate control signals for one or more artificial limbs and the system comprises one or more sets of dedicated electrodes, each placed in relation to a muscle, for receipt of the electromyographic (EMG) signals.

By using dedicated electrodes, i.e. electrodes designed and placed in such manner that the signals picked up by each of these electrodes emanate from a predefined source, e.g. a certain muscle or a certain compartment of a muscle, electromyographic (EMG) signals originating from well-defined sources may be picked up.

Consequently, EMG signals stemming from a muscle which would be activated by a human being when this human being would move a part of his body, e.g. a limb or a

part of a limb replaced by a prosthesis, may be detected, picked up and used to control the corresponding prosthesis or corresponding part of the prosthesis.

Thus, the system allows the user to move the prosthesis or part of the prosthesis in a highly intuitive way.

Further, by using the system, it will be possible to perform relatively complex movements of a prosthesis or part/parts thereof, as EMG signals may be received from muscles that would normally have been activated by the user of the prosthesis when performing the natural movements of missing body parts. These signals may thus be used to control the corresponding prosthesis parts, whereby the user may perform the desired movements intuitively, i.e. without having to learn to move particular muscle groups in a particular way and/or without having to activate switch-over mechanisms etc.

A further advantage of the system is related to environmental control, as the EMG control system may be applied for controlling light, appliances etc., which the user desires to control, e.g. turn on and off. Such an environmental control function may be incorporated in the EMG control system for controlling a prosthesis, whereby the user would be able to control such appliances, for example via wireless control, without actually having to manipulate a control means, e.g. a switch.

According to the preferred embodiment~~, as stated in claim 13~~, the one or more dedicated sets of electrodes of the system may be configured for subcutaneous, epimesial or intramuscular use, whereby it is ensured that relatively strong EMG signals from the corresponding muscle will be received by the electrode and that these signals will have a relatively high signal/noise ratio without interference from signals stemming from other sources, e.g. other muscles (cross talk).

Further, ~~as stated in claim 14,~~ said one or more sets of dedicated electrodes of the system may be configured for implantation in a muscle or muscles, whereby the

EMG signals will be received by the electrodes of the system in a relatively powerful form and without cross talk from other sources of EMG signals.

The muscles in which the sets of electrodes are implanted may for example be residual muscles related to a missing part of the body replaced by a prosthesis, e.g. muscles in an arm of a below elbow (BE) amputee. However, the sets of electrodes may be implanted in any residual limb or other muscles as desired in order to improve the EMG signal pattern discriminality. For example, a muscle in a shoulder part of an amputee may provide resourceful EMG signal information relating to the desired movements of for example a hand or an arm, whereby the functionality of the system may be enhanced.

~~As stated in claim 15, t~~The system may comprise means for transmitting the electromyographic (EMG) signals from said one or more sets of dedicated electrodes to signal processing means by wireless transmission, whereby the disadvantages and/or discomfort associated with signal wires protruding through the skin of the user may be avoided.

According to a preferred embodiment of the system, ~~and as stated in claim 16,~~ the system comprises signal processing means for producing control signals for the artificial limb(s), said signal processing means utilizing a pattern recognition method. By this system, the control signals may be produced in an advantageous manner whereby the control signals may consistently lead to the desired movements of the prosthesis and/or part/parts thereof irrespective of the fact that the EMG signals may vary in form and/or amplitude.

~~As stated in claim 17, t~~The system may comprise an artificial neural network (ANN) for generating control signals for the artificial limb(s), whereby the pattern recognition method may be performed by the system in a particularly advantageous manner.

Preferably, ~~as stated in claim 18,~~ the system may comprise four or more sets of dedicated electrodes placed in relation to at least four muscles, or combinations of func-

tional distinct muscle compartments, for receipt of electromyographic (EMG) signals. By this system, a sufficient number of distinct EMG signals may be provided in order to achieve at least four different movements of a limb or part/parts thereof.

~~As stated in claim 19, t~~The system may be utilized to control an artificial arm and/or hand wherein one or more electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus and Extensor Pollicis Longus. This system may provide at least four different movements of the artificial arm or part/parts thereof, for example closing and opening of a hand in a palmer grasp mode and closing and opening of a hand in a lateral grasp (also referred to as a key grip) mode.

~~As stated in claim 20, t~~The system may be utilized to control an artificial arm and/or hand, wherein one or more electrodes is/are placed in relation to at least the following muscles: Flexor Digitorum, Extensor Digitorum, Flexor Pollicis Longus, Extensor Pollicis Longus, Pronator Teres, Supinator, Flexor Carpi Radialis and Extensor Carpi Radialis. By this system, an artificial arm with an even larger degree of freedom may be controlled in a user-friendly and highly intuitive manner by the user. An artificial arm may for example be configured for opening/closing the hand and performing a palmer or a key grip, rotating or flexing the wrist, extending or flexing the fingers and the thumb (selectively) etc., making all these functions controllable by the amputee (the user) in a natural and highly intuitive manner.

The system may~~, as stated in claim 21,~~ advantageously comprise two or more sets of dedicated electrodes placed in relation to at least one muscle, wherein said two or more dedicated electrodes are placed in relation to different parts of said at least one muscle. Hereby, EMG signals from different parts of the muscle may be picked up by the system. These EMG signals may differ and may be used by the system to achieve an even more complex and detailed pattern of movements performed by a prosthesis such as an artificial limb.

Finally, ~~as stated in claim 22,~~ the system may comprise one or more sets of electroneurographic (ENG) electrodes for receiving electroneurographic (ENG) signals which may be used as complimentary signals for generating control signals.

Hereby, further information concerning a desired movement may be provided and used to control a prosthesis. In cases where EMG signals may not be recorded, for example EMG signals stemming from muscles which are absent, in particular the intrinsic muscles of the hand, it may be possible to record corresponding ENG signals, for example from the trunk nerves in the upper arm. These ENG signals will contain information complimentary to the EMG signals when generating control signals, whereby an improved control system for a prosthesis is provided. The ENG electrodes for recording ENG signals from the nerves may be configured in a number of ways known to a person skilled in the art.

~~**Figures**~~BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The invention will be described below with reference to the drawings ~~of~~in which

~~f~~Fig. 1 shows a cross section of the lower part of an arm illustrating the suggested positioning of dedicated electromyographic (EMG) electrodes according to the invention,

~~f~~Fig. 2 shows an example of an electromyographic (EMG) signal picked up by a set~~s~~ of EMG electrodes according to the invention,

~~f~~Fig. 3 illustrates a system for recording, processing and evaluating EMG signals from a human being, and

~~f~~Fig. 4 illustrates a block diagram, wherein a pattern recognition circuit with artificial neural networks are utilized to control an artificial limb.

~~**Detailed description**~~DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 illustrates a cross section of the right forearm of a human being, for example a human being who has lost a hand and perhaps part of the lower arm. The cross sec-

tion shown in ~~f~~Fig. 1 thus illustrates the residual muscles in the remaining part of the lower arm.

The cross section might be an image of the arm provided by an MRI (magnetic resonance imaging) scanner, and the MRI technique may also be employed when implanting the electrodes according to the invention.

The view is from distal to proximal with the Dorsal surface at the top and with the Radial surface to the left of the figure. The figure indicates the relevant residual muscles for recording electromyographic (EMG) signals:

Flexor digitorum profundus 1,
Flexor digitorum superficialis 2,
Extensor digitorum 3,
Flexor pollicis longus 4,
Extensor pollicis longus 5,
Supinator 6,
Pronator teres 7,
Flexor carpi radials8,
Flexor carpi ulnaris 9,
Extensor carpi radialis brevis 10,
Extensor carpi radialis longus 11,
Extensor carpi ulnaris 12.

From the figure, it may be observed that several of these muscles are placed relatively deep in the arm and are not directly accessible. EMG signals from these muscles will thus be difficult to obtain with surface electrodes. In particular, Extensor pollicis longus 5, Supinator 6 and Flexor pollicis longus 4 are inaccessible and cannot be recorded by using surface mounted electrodes.

A selection of palmer grip versus key grip can be achieved by analyzing the EMG activity of four muscle groups:

Finger flexors: This can be Flexor digitorum profundus 1 or Flexor digitorum superficialis 2.
Finger extensors: This can be extensor digitorum 3.

Thumb flexor: This can be Flexor pollicis longus 4.
Thumb extensor: This can be Extensor pollicis longus 5.

A selection of the function of wrist movements (flexion; extension; pronation and supination) can be achieved by analyzing the EMG activity of four muscle groups:

Wrist supination: This can be Supinator 6.
Wrist pronation: This can be Pronator teres 7.

Wrist flexion: This can be Flexor carpi radials 8 or Flexor carpi ulnaris 9.
Wrist extension: This can be Extensor carpi radialis brevis 10, Extensor carpi radialis longus 11 or Extensor carpi ulnaris 12.

Electrodes for receiving electromyographic (EMG) signals from the muscles may be implanted in these muscles, for example in special parts of these muscles, where the signals may be picked up in a relatively strong form, with or without only a small amount of cross talk.

The electrodes may be monopolar, bipolar,tripolar etc. The electrodes may be placed percutaneously, whereby the signal wires will have to protrude through the skin of the user. This has some disadvantages such as the risk of infection and the discomfort to the user which makes the use of electrodes, which are totally implanted, preferable.

When totally implanted electrodes are used, the signals may be transmitted for example by telemetry by electromagnetic, optical or other means, to the surface of the arm and/or to the processing means of the signals.

Fig. 2 illustrates an example of a EMG signal picked up from a residual muscle in a lower arm. The signal from the EMG electrode has been processed, e.g. amplified (1000 – 10000), band-pass filtered (10 Hz – 1 kHz) and sampled (2 kHz). Further, the signal has been processed in order to remove DC-offset and motion artifacts (digital high pass, Butterworth order 4, 20 Hz). Finally, the signal has been full-wave rectified and a moving average signal has been provided (over a 25 ms sliding window) before the signal has been processed in order to determine an onset.

This has been done by applying a 200 ms sliding window 21 to the moving average signal. If the number of samples in this 200 ms window 21 exceeds an appropriate threshold value for at least 175 ms (not necessarily consecutively), the first point of this window 21 is labeled as the onset 22. Initial spikes 23 will thus not have any influence on the detection of the onset event 22.

Following the detection of an onset event, a search for an offset event, for example when the number of samples below the appropriate threshold exceeds 150 ms, takes place.

This is only an example of the signal processing to determine onset and offset. Other algorithms may be applied in connection with the invention.

Fig. 3 illustrates a system for recording, processing and evaluating EMG signals from a human being, for example in order to examine the signals from implanted electrodes, and for optimizing the positioning of electrodes, the signal processing means or the control means or in order to train a user of a system according to the invention.

A human being 30 who has lost a hand has had a number of EMG electrodes implanted in the forearm 31. These are connected by means of wires 32 to a signal processing means 33 comprising amplifiers and filters. The output from the processing means 33 is delivered to a data acquisition board and computer 34, where the

signals are stored and/or visualized. Further, the system comprises a computer 35 with a screen, on which an animation target 36 is shown.

The animation target 36 is a hand which may perform different movements, grips, etc., and the amputee 30 is asked to mimic with his phantom hand the animations performed by the hand 36. The signals may be stored by the computer 34, and the recorded signals corresponding to the movements and grips intended by the amputee may be used to configure a system according to the invention. In particular, the system illustrated in fig. 3 may be utilized for training artificial neural networks in order to configure a control system according to the invention and in order to individualize such a system.

Fig 4 illustrates a control system according to the invention wherein artificial neural networks (ANN) are utilized. A prosthesis 41 in the form of an artificial hand 41 is illustrated as the object to be controlled by the system. A number of EMG electrodes 43a – 43n are illustrated, each receiving EMG signals 42a – 42n, respectively. The output signals 44a - 44n are amplified, band-pass filtered and transmitted, for example by telemetry by electromagnetic, optical or other means, to a signal processing means 45, comprising for example additional amplifiers, filters etc. The output 46 from this processing means is led to a pattern recognition circuit 47 comprising for example artificial neural networks, wherein the signals are processed in order to determine which movements and/or grips are desired by the user.

From the pattern recognition circuit 47, a signal is sent to a control circuit 48 containing for example power and control circuits, and finally an output signal is led to the driving means 49 of the artificial hand 41.

In addition to the EMG electrodes 43a – 43n delivering signals 44a – 44n to the signal processing means 45, a number of ENG (electroneurographic) electrodes (not shown) may be utilized in connection with the system, providing additional information of the intended movements.

In this case, the invention has been described in relation to an artificial limb in the form of a hand. Evidently, the invention may be used in relation to prostheses in general, e.g. artificial arms, legs, feet, etc.

Further, the invention can be applied for environmental control in addition to control of prostheses. For example, a user may utilize the system to turn lights on and off, to open and close power-controlled doors, to control communication means, to control input to communication means, e.g. computers, to control vehicles, to control appliances etc.

1/3

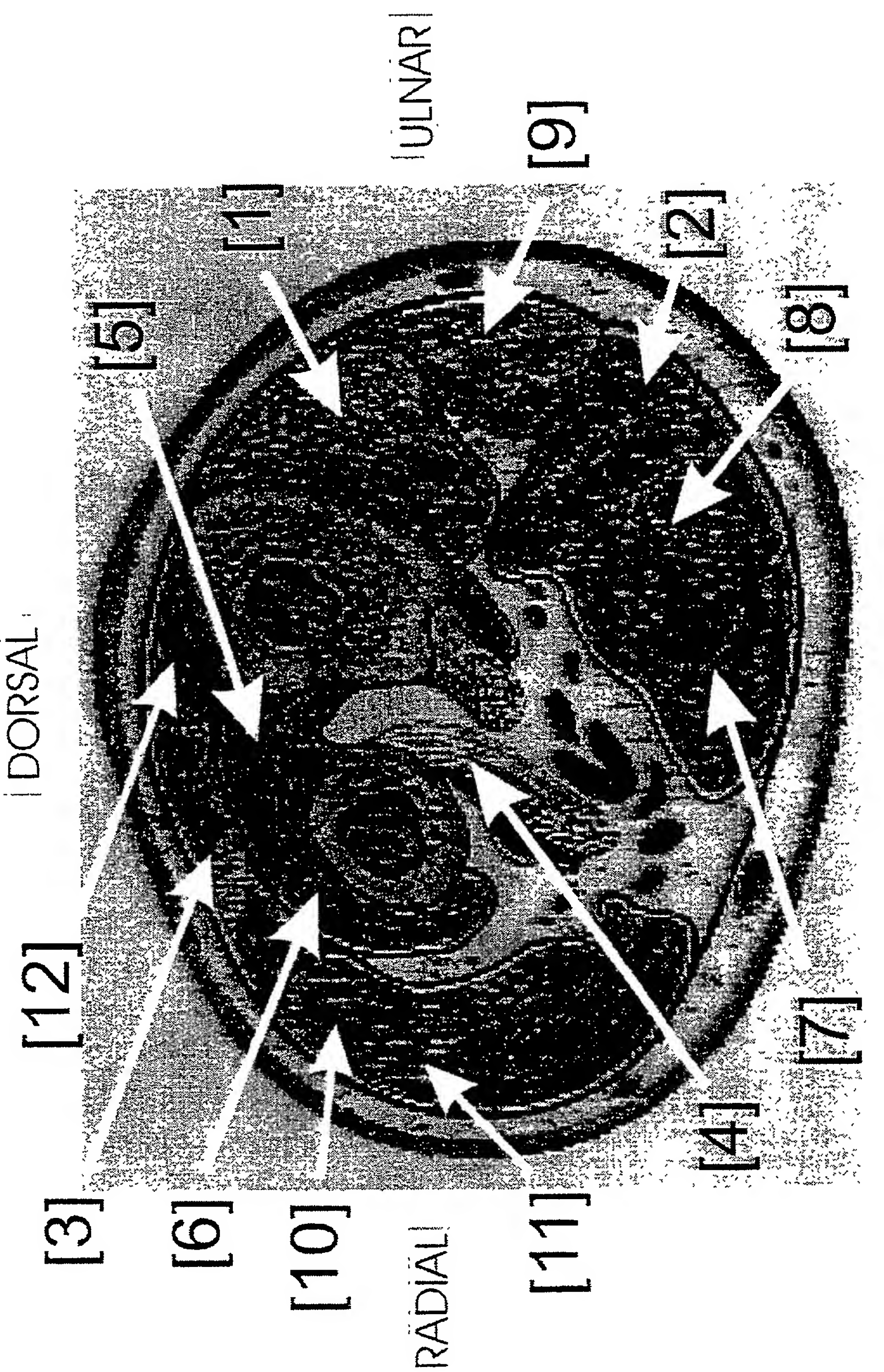

Fig. 1

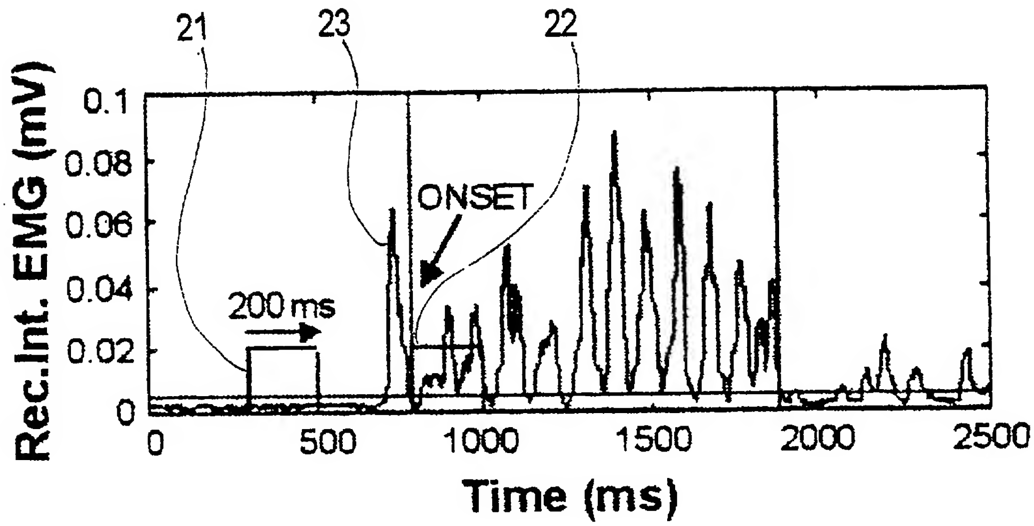
21
23
22
ONSET
200 ms
Rec.Int. EMG (mV)
0.1
0.08
0.06
0.04
0.02
0
0
500
1000
1500
2000
2500
Time (ms)

Fig. 2

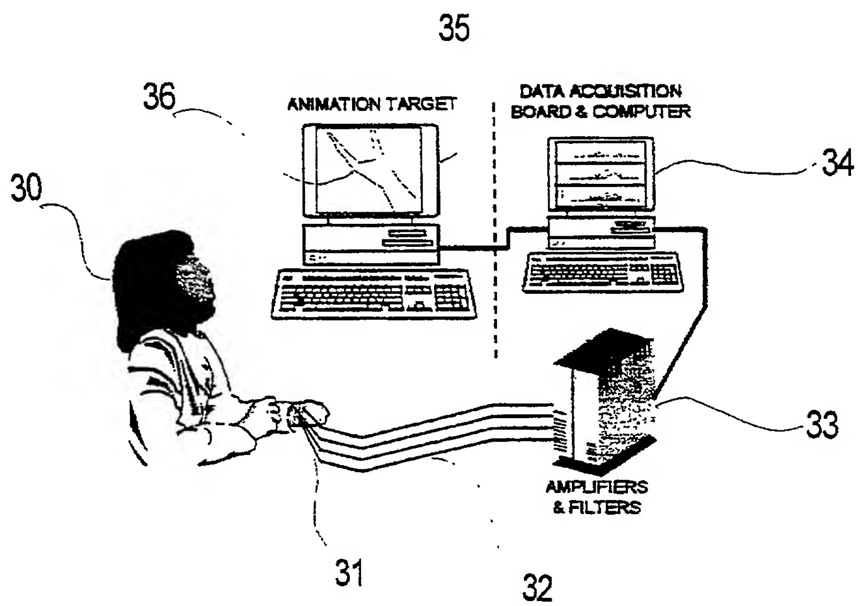
35
36
ANIMATION TARGET
DATA ACQUISITION BOARD & COMPUTER
34
30
33
AMPLIFIERS & FILTERS
31
32

Fig. 3

3/3

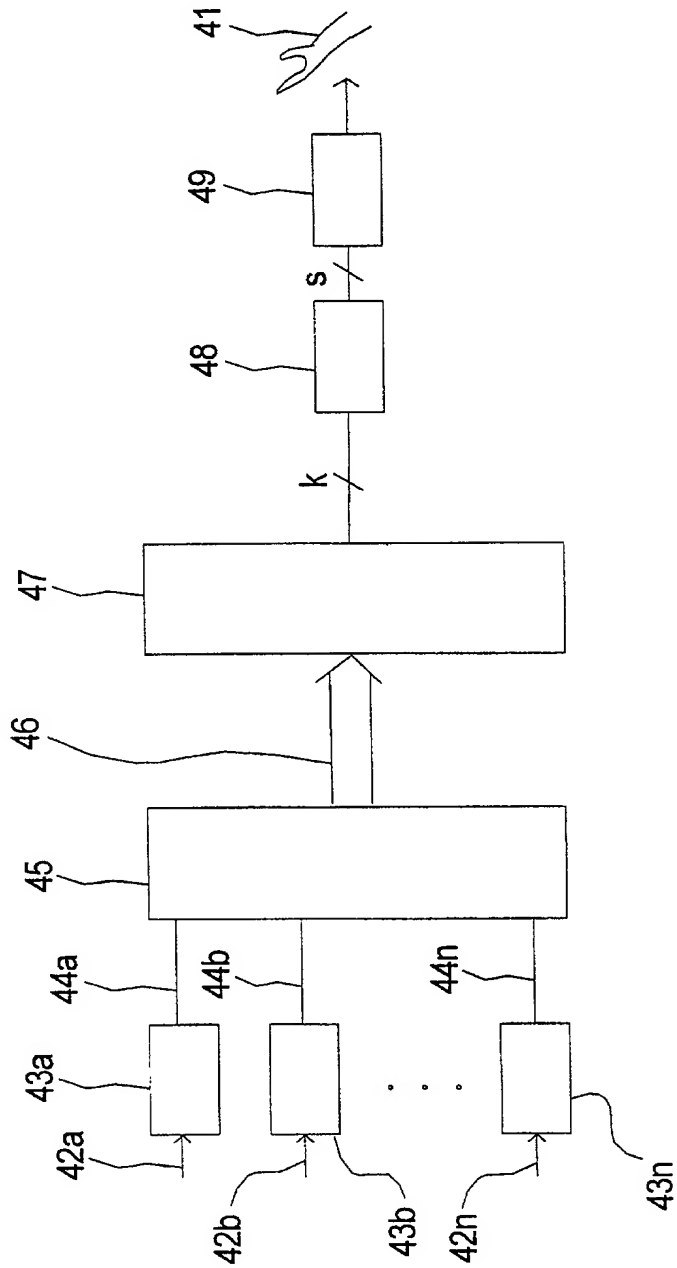

Fig. 4

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my/our name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled EMG CONTROL OF PROSTHESIS the specification of which

(check one)

_____ is attached hereto.

__x__ was filed on 21 August 2000 as
Application Serial No. PCT/DK00/00464
and was amended on 3 December 2001
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, 1.56(a).

I hereby claim foreign priority benefits under title 35, United States Code 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s).

(Number)	(Country)	(Day/Month/Year Filed)	Priority Claimed
PA 1999 01149	Denmark	20 August 1999	Yes

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

PCT/DK00/00464	21 August 2000	Pending
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

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PROVISIONAL APPLICATION NUMBER	FILING DATE

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